Harnessing biotechnology in agriculture

"Green" Biotechnology

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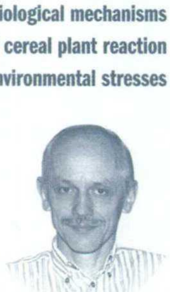

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New technologies are difficult for the public to accept. Nevertheless, many countries have already managed to introduce laws that regulate ways of handling GMOs and new foods

The English clergyman Thomas Malthus developed a theory in the 18th century stating that population numbers increase at a geometric rate, while food resources increase at most at an arithmetic rate. This stunningly simple argumentation pointed to the inevitability of hunger and thus a struggle for survival. Nevertheless, the economic history of Europe and America over the past 200 years has seemed to indicate that Malthus's theory does not hold, at least with respect to mankind - growth in food production has been proportional to population growth, or even greater in certain periods and countries. Progress in the natural and agricultural sciences has enabled the developed countries to escape this so-called Malthusian trap.

Since the 1950s, new technological advances (mechanical cultivation, fertilization, chemical means of counteracting diseases and weeds, irrigation) and genetic science have given rise to what is frequently dubbed a "green revolution," a significant surge in the efficiency of agricultural production. These processes have enabled food production to continue to keep pace or even sometimes exceed population growth.

Nevertheless, the achievements of this "green revolution" have come with a price-tag: the spread of high-output modern strains has led to a significant downturn in biological diversity of the main crop species, especially acute in their places of origin; the use of mineral fertilizers and pesticides causes their remains to accumulate in the soil and water; irrigation leads to salinification, etc. Moreover, the "green revolution" has only enabled us to avoid the Malthusian trap for a limited time. The FAO forecasts that humanity will be surging by some 70 million people (twice Poland's population) every year. Feeding such a burgeoning population will require increased cereal production. It is now practically impossible for such growth to be achieved purely by expanding harvests, since the reserves of arable land are now very limited and further expansion can only come at the expense of forests, including tropical ones.

Malthus's ghost

The views professed in wealthy countries about agricultural overproduction and the possibilities of reverting to extensive production systems have been based on a confluence of circumstances (cheap energy, rapid growth in agricultural efficiency) of only very limited temporal and spatial validity. Higher energy prices combined with

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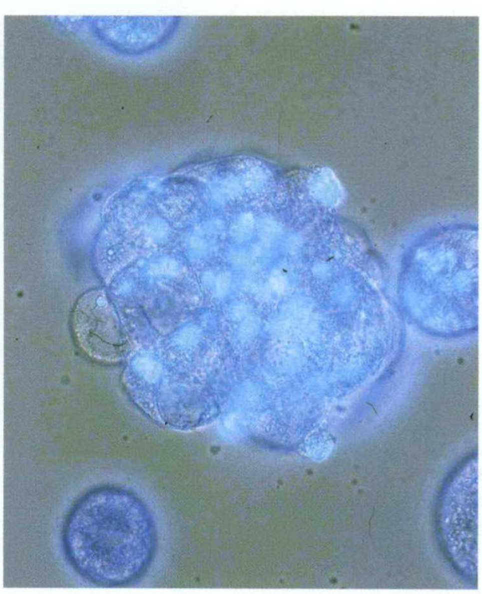

In vitro culture techniques available today enable entire plants to be regenerated from a single cell. Here, the nuclei of cells undergoing division are visible

Katarzyna Grelewska

Breeding a new, better cultivar of a cereal plant takes more than 10 years

a rising standard of living in the populous countries of Asia have caused Malthus's predictions to again become more realistic.

The existing mechanism for boosting harvests has in large part become exhausted, and hope that further growth in food production might remain on par with population growth now lies in increasing the efficiency of production per unit of cultivated area. The current achievements and future prospects of genetic engineering open up such possibilities.

The discovery of the structure of DNA by Watson and Crick 55 years ago had a fundamental significance similar to that of Darwin's announcement of the theory of evolution 150 years ago. The practical applications of those findings are nowadays bringing great changes in many fields of life.

Paradoxically, the emergence of such transformations has coincided with a slump in public faith and trust in science and researchers, meaning that the necessary changes are now encountering great resistance from society. This is a situation completely different from the widespread affirmation and acceptance that accompanied the development of technology through the middle of the past century. Added to that is a kind of information overload: the mixing up of rational arguments and prejudices, making it hard for people not well-versed in highly technical aspects to make up their own mind and take a position on the issues at hand. One particularly important factor is how to inform the public about the capabilities of new technologies, while at the same time differentiating between authentic and imagined dangers.

Benefits and threats

The development of biotechnology is yielding tangible benefits in medicine, environmental protection, industry, and forging an innovative economy. Opponents to GMOs perceive various threats to people's health, ecology, socioeconomic relations, ethics, and the distribution of information. Interestingly, new products used in health care, such as human insulin produced by bacteria by the Warsaw-based company Bioton, gain public acceptance quite easily. The appearance of such Polish insulin on the market caused a significant drop in the price of the hormone, used for treating diabetes. But things are different for genetically modified foods.

Mankind has been seeking ways to boost crop yields and raise food quality by breeding new strains of cultivated plants for millenia. The plants currently cultivated also arose through the selection of the most advantageous genotypes and careful analysis of progeny. However, it takes more than 10 years to introduce new traits like resistance to disease or to create a more effective combination of parental genes. That is why, aside from classical methods, breeders are now looking to advanced scientific techniques for accelerating the breeding of desirable genotypes. The newest method of this sort involves direct gene transfer, characterized by greater precision and specific information about the expected final product. Conventional breeding methods and genetic engineering complement one another as ways of obtaining strains with desirable characteristics.

Third generation

The use of modern biotechnological techniques in plant breeding is expected to yield concrete results in developing foods and other products. There are now seen to be three generations of genetically modified plants. The first contains genes which condition for traits that are significant from the standpoint of cultivation, such as herbicide tolerance or resistance to insects and disease. Cultivation of such plants brings benefits to farmers in the form of lower use of pesticides or labor.

The second generation consists of plants whose improved traits manifest themselves in the final stage of their use. Such plants will be a source of improved food products. The genes introduced into them may alter the function of certain proteins. For instance, an improved amino acid composition or an increased content of a certain vitamin (such as in the modified "Golden Rice," with an increased provitamin A content) may improve food quality and help prevent dangerous diseases, such as childhood blindness caused in Asia by vitamin A deficiency. Genetic modification may also contribute to improving the flavor of fruits and vegetables, or to reducing allergen content in foods. Such modification therefore generates direct benefits for consumers.

The third and latest generation consists of GM plants that function like bio-factories, producing concrete substances utilized in various industries. Plants with an altered fatty acid synthesis pathway are finding applications in the production of industrial oils and can also produce biopolymers to replace petroleum-derived compounds.

Modifications in the oil content and fatty acid breakdown in plants and seeds may be important for food production. Such research is customarily performed on the rapeseed plant, widely used in oil production. Work is underway on breeding a rape variety with high stearic, palmitic-myristic, and erucic acid content. One rapeseed breed producing high content of lauric acid, an oil used in the confectionary industry, has already been commercialized. Modified soy and sunflower plants, in turn, can produce large quantities of oleic acid, one of the most important unsaturated fatty acids, valuable for the food industry.

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Plant breeding methods resting on solid scientific foundations are faster and more efficient. Here: a method of regenerating balanced plant lines based on individual haploid cells

Public opinion

Many transgenetic plants have appeared on the market since the first tomatoes characterized by delayed ripening were sold in the US in 1994, but worldwide production is nowadays dominated by four species: herbicide-tolerant soy, cotton, and rapeseed, plus pest-resistant cotton and corn.

Worldwide surface area planted with transgenetic plants has significantly increased, and transgenetic plants are now cultivated on a large scale in the US, Argentina, Brazil, Canada, and China. Within the EU, only certain countries have introduced GM plants into cultivation, albeit on very small surface areas.

The public, whose mood is often artificially swayed, unfortunately finds such new technologies hard to accept. Consumer confidence was undermined by several discovered cases of food contamination that were in fact unrelated to GMOs, such as olive oil contaminated with motor oil, food contaminated with dioxins, and wine laced with glycol.

The greatest fears pertain to the impact of GM plants on the environment and on the health of consumers. The most frequently voiced fears include: the emergence of "super-weeds" or "super-pests" (as a consequence of excessive selective pressure), the negative impact of GM plants on soil ecosystems and other organisms, decreased biodiversity, the transfer of foreign genes to other plant species related to a modified crop, and toxic or allergenic effects of consuming modified foods. Moreover, there are fears about farmers becoming overly dependent upon large corporations selling GM seeds.

Those fears, albeit justified, mainly address dangers of a potential nature, and not every danger is associated with every GMO. Moreover, here we are dealing solely with the *possibility* of undesirable effects. Everything depends on the given GMO. The question of whether the use of GMOs is safe is just as impossible to answer unequivocally as the question of whether mushrooms are poisonous.

EU directives

EU law has been enacted based on two fundamental principles. The first is the precautionary principle, which calls for measures to be taken to prevent undesired effects. The other is the case-by-case principle, under which each GMO should be treated individually and assertions about the safety or danger of utilizing GMOs in general are seen as unfounded. Especially assertions that GM cultivation, as such, harms the environment. Issues related to the use of GMOs have also been regulated in national-level law: Polish regulations are in large part based on EU provisions and must be consistent with them.

Any product entering the EU market must pass through a procedure of authorization. Before being approved, every product is studied in detail in terms of its environmental impact and its safety for the health and well-being of humans and animals. GM products must be correspondingly labeled, giving consumers a free choice.

The EU has set up a network of reference laboratories, tasked with analyzing modified products and detecting GMOs in products already available on the market. They work together with the reference laboratories of other countries and with environment ministers. One such laboratory in Poland is the GMO Control Laboratory at the Plant Breeding and Acclimatization Institute in Radzików.

The laboratory's establishment at the Institute represents the outcome of research carried out here since the mid-1980s. In 1993 the Institute obtained the world's first transgenetic triticale plants, of important economic significance. At the same time transgenetic potatoes were also obtained in collaboration with the Institute of Biochemistry and Biophysics, Polish Academy of Sciences. Subsequent generations of triticale have been under study for the past 15 years. Current research focused on corn aims to lay the groundwork for developing principles for the coexistence of conventional, organic, and GM crops in Poland.

Common problem

The problem of transgenetic crops and products derived from them has to be perceived on a global scale, because socioeconomic events like price increases and food shortages affect the whole world and their consequences are felt by everyone. We are now witnessing the kind of phenomenon described by Norman Borlaug back in the 1970s: the power of modern science grappling with the power of natural human population growth. The problem is gaining even greater significance today, and we cannot pretend it does not pertain to us contemporary Europeans. ■

Further reading:

Forsman Z.K. (2004). Community Regulation of Genetically Modified Organisms: A Difficult Relationship Between Law and Science. *European Law J.*, *5*, 580–594.

Janusz Zimny

Can the intellectual potential of science manage to avert world food shortages?