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CONVENTIONAL AND MOLECULAR PLANT BREEDING: BENEFIT AND RISKS IN SEED AND PLANT QUALITY IMPROVEMENT

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Abstract

Conventional breeding technologies are including selection, mutagenic breeding and somaclonal variation. Molecular breeding includeMAS,"omics technology and genetic modification genetically modified organisms (GMO) with specific changes in genome by genetic engineering. The main goal of breeding is to increase stable yield, which depends on the genetic potentional and tolerance/resistance to biotic and abiotic stresses, but recently it is intensive working to improve the properties and quality of grain.Genetically modified *RoundupReady* soybean has 2.3% yields increase but 2 – 5 times higher amount of herbicide applied. By conventional breeding maize average is increased from 2t/ha 1947 to more than 6t/ha during 2010. At Maize Research Institute "Zemun Polje" among 665 created and officially recognized hybrids by state officials, 83 has improved quality.Similar results were obtained in other institution as well as in other plant species (wheat, soybean, sunflower, tomato *etc*). By genetic engineering it is possible to introduce genes not only from plant species but from evolutionary different organisms (bacteria, viruses, fungi, *antisense genes*) and create GMO. Food produced from soybean and maize, has been on the market 1996. GM crops are grown in the world at over 160mil/ha,mainly soybeans, maize cotton and canola, In addition to tolerance to herbicides, drought and deseases has been much work on improving the quality of grain (rice with increased content of beta carotene, oil crops with modified fatty acid content,, altered protein, starch). In addition to food obtained directly from genetically modified plants containing GM ingradients or GM derived ingradients the standard process of food production, can be improved by adding different genetically modified microorganisms as sources of enzymes. A lot of controversy is connected with GMO – food, including biological safety, ecological effect and particularly economic aspect due to low for GMO plants patenting in order to protect intellectual property.

Key words: *plant breeding, molecular, conventional, GMO, food*

Introduction

Food is essential for the survival of human beings. Long - term improvements in well being can only be accomplished by providing people with access to food, skills, education and opportunities. Health involves ensuring adequate nutrition and safeguards against unsafe food. Technical progress in Agriculture and food production traditionally occurred through a process of selection in the field and adaptation of traditional landraces of crops. This was supplemented by purposive breeding of new varieties of crops, mainly through crossing varieties with desirable characteristics. Conventional breeding is cumulative science and seeds accumulate innovations, but can be very time consuming and is often not very accurate. Genetic engineering can create plants with the exact desired trait as plant geneticists can isolate a gene responsible for drought tolerance, pest resistance, herbicide tolerance, disease resistance, cold tolerance, salinity tolerance, nutrition, pharmaceuticals, phitoremediation *etc.* and insert that gene into a different plant. Genetic modification offers both faster crop adaptation and a biological, rather than chemical, approach to yield increases. GM foods or GMO is most commonly used term to refer to crop plants created for production of safe food for human or animal consumption using this technology.

In recent years the development of food and agriculture sector is being conceptualized globally. For example, food – borne disease originating in one farm field my generate health problem in several continents. In every large city on earth it is possible eat at "fast food" restaurant and drink the same bottles soft drinks. Also important and actual question is whether GM can solve world hunger (Diouf and Sheeren, 2010).

Overview of current result in GM and GMO – food research and commercialization

- Comparison of conventional and molecular plant breeding effect on yield

The main goal in agriculture, independent on plant species, whether conventional or new technologies are applied, is increasing of yield and quality improvement. Modern science requires from breeders to develop new highly yielding variety and hybrids tolerant to various stress factors in as shorter as possible period. These requirements resulted in needs for the development and the application of contemporary and efficient techniques and methods in plant breeding. With increasing knowledge and improved technology, breeders have developed ways to enhance the speed, accuracy and scope of the breeding process. Achievement in various fields of science have resulted in the development of new approaches and techniques in plant breeding such as molecular marker technology, MAS, "omica" technologies, transgenesis and cisgenesis. Marker assisted breeding allows breeders to determine whether desired traits are present in a new variety at an early stage in the breeding programme. Genomics research is generating new tools, such as functional molecular markers and informatics, as well as new knowledge about statistics and inheritance phenomena that could increase the efficiency and precision of crop improvement. The development of new techniques in plant breeding did not lead to the replacement of the older methods. The use of all available technologies is essential for plant breeding. Conventional breeding techniques, transgenesis and new plant breeding techniques are essential components of what we could call the plant breeders' toolbox.

The study concluded that in the United States, other agricultural methods have made a much greater contribution to national crop yield increases in recent years than genetic engineering. According to results from different studies including (Drinić *et al.* 2007) the genetic yield potential of ZP maize hybrids over last 40 years amounted to 1000 kg per ha $^{-1}$ per year. More than 665 high yielding hybrids have been officially recognized by State regulations since 1964. including hybrids for special purposes and industrial use as high - oil maize, high - lysine maize, waxy maize, white maize, pop corn and sweet corn, inbred lines and hybrids resistant to economically important diseases and hybrids suitable for industrial use (Saratlić *et al.* 2007., Babić *et al*, 2011). Hybrids for special purposes are obtained by introducing genes controlling desired trait through conventional crossing procedure. The same or similar results in maize breeding were obtained in different countries as well as with breeding of other plant species (wheat, soybean, tomato, sunflower, sugar beet *etc*).

Data published by United States Department of Agriculture showed that the yield contribution of engineered genes is a modest fraction—about 14 percent—of the maize yield increase since the mid 1990s. Benbrook (1999) found that genetically engineered Roundup Ready soybeans had a yield drag of 5.3% across all varieties tested. This "yield drag" is similar to what is observed when other traits are introduced into soybeans by conventional breeding (Caviness, C.E., and H.J. Walters. 1971) and may not be due to the *Roundup Ready* trait or the genetically modified nature of the crop. There have been no reports of "yield drag" with the other *Roundup Ready* crops maize, sorghum or canola. Research published by Qaim *et al.* (*2003*) has shown that the use of genetically modified *Bt* cotton in India increased yields by 60% over the period 1998–2001, while the number of applications of insecticides against bollworm were three times less on average. In paper published by Carpenter (2010) has been reported that the results of 49 peer - reviewed studies on GM crops worldwide average, farmers in developed countries experienced increase in yield of 6% and in underdeveloped countries of 29 %. Monsanto claimed average yield was reduced by 25% in those fields explained the corn varieties were affected by a mistake made in the seed breeding process but Marian Mayet, an environmental activist and director of the Africa Centre for Biosecurity in Johannesburg, called (http://www.digitaljournal.com/article/270101, retrieved 24 October 2010.) for a government investigation and asserted that the biotechnology was at fault, "*You cannot make a 'mistake' with three different varieties of corn*". According to Brasher, (2010) in 2009 South African farmers planted 1,900,000 hectares (4,700,000 acres) of GM maize (73% of the total crop).

- Genetically modified crops

Among huge number of domesticated plant species and varieties in last two decades scientists did develop genetically modified crops, source of food and feed, such as:

Soybean (resistant to glyphosate or glufosinate herbicides), high oleic, **Maize** resistant to glyphosate or glufosinate herbicides; insect resistant via producing *Bt* proteins, some previously used as pesticides in organic crop production: vitamin-enriched corn derived from South African white corn variety M37W has bright orange kernels, with 169x increase in beta carotene, 6x the vitamin C and 2x folate (Shaista Naqvi, et al. (2009), **Cotton** - cottonseed oil, pest-resistant cotton; **Alfalfa,** resistant to glyphosate or glufosinate herbicides, **Hawaiian papaya** variety is resistant to the papaya ringspot virus (Manshardt, 1998); **Tomatoes,** variety in which the production of the enzyme polygalacturonase (PG) is suppressed, retarding fruit softening after harvesting (U.S. Food and Drug Administration 1994), **Canola/ Rapeseed**, resistance to herbicides (glyphosate or glufosinate), high laurate canola (U.S. Food and Drug Administration, 1994) http://en.wikipedia.org/wiki/Genetically_modified_food_-cite_note-22, **Sugarcane**, resistance to certain pesticides, high sucrose content; **Sugar beet,** resistance to glyphosate, glufosinate herbicides; **Rice,** Golden Rice: genetically modified to contain beta-carotene (a source of vitamin A), **Squash,** (Zucchini/ Courgette, resistance to watermelon, cucumber and zucchini/courgette yellow mosaic viruses (Pocket K , 2010); **Sweet peppers,** resistance to virus (Paroda 2008). Varius enzymes from genetically engineered micro-organisms are in use for the food production. These include *alpha-amylase* from bacteria, which converts starch to simple sugars, *chymosin* from bacteria or fungi that clots milk protein for cheese making, and pectin esterase from fungi which improves fruit juice clarity (Panesar et al. (2010).

Comparing transgenic wheat with conventionally bred wheat, Baker *et al,* (2006) concluded that "...transgenic plants could be considered substantially equivalent to untransformed parental lines." Ridley *et al.* (2002) reported that genetically engineered maize was equivalent to conventional maize for proximates, fiber, amino acids, fatty acids, vitamin E, nine minerals, phytic acid, trypsin inhibitor, and secondary metabolites. Cheng *et al.* (2008) showed that genetic engineering of soybeans cause's smaller unintended changes than are seen with traditional breeding. Comparing genetically engineered tomato *Lycopersicon esculentum* and *Nicotiana benthamiana.* a close relative of tobacco (U.S. Food and Drug Administration, 1994) with their untransformed counterparts and concluded that genetic engineering did not significantly affect the plants' proteomic profile.

- Genetically modified foods - GM foods or biotech foods

World Health Organization (WHO report, January 2003) put on the table twenty questions on genetically modified foods : What are genetically modified (GM) organisms and GM foods? Why are GM foods produced? Are GM foods assessed differently from traditional food? How are the potential risks to human health determined? What are the main issues of concern for human health? How is a risk assessment for the environment performed? What are the issues of concern for the environment? Are GM foods safe? How are GM foods regulated nationally? What kind of GM foods are on the market internationally? What happens when GM foods are traded internationally? What happens when GM foods are traded internationally? Have GM products on the international market passed a risk assessment? Why has there been concern about GM foods among some politicians, public interest groups and consumers, especially in Europe? How has this concern affected the marketing of GM foods in the European Union? What is the state of public debate on GM foods in other regions of the world? Are people's reactions related to the different attitudes to food in various regions of the world? Are there implications for the rights of farmers to own their crops? Why are certain groups concerned about the growing influence of the chemical industry on agriculture? What further developments can be expected in the area of GMOs? What is WHO doing to improve the evaluation of GM foods? Conventional techniques by which humans modify food organisms include selective breeding, plant breeding, animal breeding and somaclonal variation. Genetically modified foods (GM foods, or biotech foods) are foods derived from genetically modified organisms which possess specific changes introduced into their DNA by genetic engineering techniques. Flavr Savr, a genetically modified tomato was the first commercially grown genetically engeneered food to be granted a license for human consumption. It was produced by Californian company Calgene and submitted to the U.S Food and Drag Administration (FDA) in 1992.

Animal products have also been developed, although as of July 2010 none are currently on the market (Holmes 2010). http://en.wikipedia.org/wiki/Genetically_modified_food - cite_note-1. In 2006 (Fiester 2006., Kang JX *et al*. 2007) a pig was engineered to produce omega-3 fatty acids through the expression of around worm gene (Lai et al. (2006). Researchers have also developed a genetically modified breed of pigs that are able to absorb plant phosphorus more efficiently, and as a consequence the phosphorus content of their manure is reduced by as much as 60% (Guelph Transgenic Pig Research Program (2005). Although enveloped, animal products are not currently on the market (Holmes, 2010).

- Genetically modified foods - GM foods or biotech foods safety

Among the key areas of controversy related to genetically engineered (GE) food is food safety. Consumers generally consider that traditional foods (that have often been eaten for thousands of years) are safe. When new foods are developed by natural methods, some of the existing characteristics of foods can be altered, either in a positive or a negative way (Diouf and Sheeran 2010**.** GMOs' proponents (Ricroch, et al, 2011) note that transgenesis has less impact on the expression of genomes or on protein and metabolite levels than conventional breeding or plant (non-directed) mutagenesis (Ricroch *et al*. 2011) An example of an allergenic plant created using traditional breeding is the kiwi.

Kuiper *et al.* (2002) suggested that "The concept of substantial equivalence is an adequate tool in order to identify safety issues related to genetically modified products that have a traditional counterpart". They also noted difficulties in applying this standard in practice, including the fact that traditional foods contain many chemicals that have toxic or carcinogenic effects and that our existing diets therefore have not been proven to be safe. Millstone *et al*. (1999) argued that all GM foods should have extensive biological, toxicological and immunological tests and that the concept of substantial equivalence based solely on chemical analyzes of the components of a food should be abandoned (Keeler and Lappé 2001), comparing Roundup ready soybean to its unmodified counterpart, noted significantly lower levels of protein than unmodified soybean". Levels of trypsin inhibitor were 27% higher and after toasting lectin was double that found in conventional soybean and both are known allergens. GM soybean also has 29% less holine, a B – complex vitamin **(**Milestone et al, 1999)

Up to date, no adverse health effects caused by GM products approved for sale have been documented, although two products failed initial safety testing and were discontinued, due to allergic reaction (WHO, 2003). Most feeding trials have observed no toxic effects and saw that GM foods were equivalent to unmodified foods. Although there is now broad scientific consensus that GE crops on the market are safe to eat (NRC, 2004) some scientists (Seralini *et al*. 2007) and advocacy groups such as Greenpeace and World Wildlife Fund call for additional and more rigorous testing of existing GM food and for approval of any new introductions of GM food (Le Curieux - Belfond *et al*., 2009).

BT toxin (a protein having insecticidal effects on certain insects, produced by a gene from a soil bacterium *Bacillus thuringiensis*) produced in genetically modified maize, has been subject of the experiment. to evaluate the correlation between maternal and fetal exposure and to determine exposure levels of the pesticides and their metabolites**.** Authors (NCBI ,2011) reported the presence of pesticides associated with GM foods in both non-pregnant women and pregnant women and their fetuses (Poulter, 2012)**.** The paper did not discuss safety implications or find any health problems. Several authors and organizations found paper to be unconvincing (de Weck, 2011, FSANZ, 2011).

There are suggestions that GM food might trigger food allergies but in a study by Lehrer and Bannon (2005) results from allergen testing of current GM foods stated that "no biotech proteins in foods have been documented to cause allergic reactions". GM soybean with enriched protein content, intended for animal feed did not reach the market due to it producing an allergic reaction. Investigation of the allergenicity were conducted by company because it was supposed that allergen was transferred unintentionally from the Brazil nut into genetically engineered soybeans, in a bid to improve soybean nutritional quality for animal feed use. Testing included, radio allergosorbent testing, immune blotting, and skin-prick testing. The tests revealed that they produced immune reactions in people with Brazil nut allergies, since the methionine rich protein happened to be a major source of Brazil nut allergy (Nordiee *et al*. 1996). Company discontinued further development of the GM soybean, due to the difficulty in ensuring that none of these soybeans entered the human food chain (Streit *et al*. 2001)

Pest-resistant field pea developed by the Australian CSIRO for use as a pasture crop was shown to cause an allergic reaction in mice. The protein added to the pea did not cause the reaction in humans or mice in isolation, but when it was expressed in the pea, it exhibited a subtly different structure which may have caused the allergic reaction. The immunologist who tested the pea noted that crops need to be evaluated case-by-case (Prescott, 2005). GM - products that failed safety testing can either be viewed as evidence that genetic modification can produce unexpected and dangerous changes in foods, or alternatively that the current tests are effective at identifying any safety problems before foods come on the market, (Key *et al*. 2008)**.**

According to Herman (2003) genetic modification can be used to remove allergens from foods, which may, for example, allow the production of soy products that would pose a smaller risk of food allergies than standard soybeans. This approach has been tried in ryegrass, which produces pollen that is a major cause of hay fever: fertile GM grass was produced that lacked the main pollen allergen, demonstrating that the production of hypoallergenic grass is also possible (Bhalla et al. 1999)**.**

Flachowsky *et al* (2005) concluded that first-generation genetically modified foods had been found to be similar in nutrition and safety to non-GM foods, but noted that second-generation foods with "significant changes in constituents" would be more difficult to test, and would require further testing. Long term effect of the use of GM food in the human diet is not known and requests multiannual tests to have reliable determination of its safety.

- Testing and regulations of GMO and GM Food

Availability of GM seed for testing is considered by some to be problematic because, due to restrictive end – user agreements, independent researchers cannot obtain GM plants to study. As a result of restrictive access to GMO seed, no truly independent research can be legally conducted on many critical questions regarding the technology" (Stutz, 2010). While recognizing that seed companies' intellectual property rights need to be protected, *Scientific American* called for the restrictions on research in the end-user agreements to be lifted immediately and for the EPA to require, as a condition of approval, that independent researchers have unrestricted access to GM products for testing (The Editors, 2009). GM Free Cymru group argues that governments should use independent studies rather than industry studies to assess crop safety and stated that independently funded researcher, Professor Bela Darvas of Debrecen University was refused Mon 863 Bt corn to use in his studies after previously publishing that a different variety of Monsanto corn was lethal to two Hungarian protected insect species and an insect classified as a rare (Hungary Bans, 2005).

In the regulation of GMOs the most marked differences occurring between the USA and Europe depending on the intended use of the products of the genetic engineering. Determination the safety of a particular GM food in USA regulates several laws (Guide to US Regulation, 2012). Crop not intended for food use is generally not reviewed by authorities responsible for food safety. The main conclusion from the efforts of more than 130 research projects, covering a period of more than 25 years of research, and involving more than 500 independent research groups, is that biotechnology, and in particular GMOs, are not per se more risky than e.g. conventional plant breeding technologies." (Acreage NASS, 2010)

When Monsanto was interested for approval in Europe to introduce a rootworm resistant (MON863) maize, Seralini, as member of the committee that reviewed MON863 for the French government, continues to be a critic of toxicity study design (Seralini et al. 2011). Authors noted that "It must be said that very few tests on humans have been carried out up to now". European Food Safety Authority (EFSA) describing the data that Monsanto provided concluded that the observed small numerical decrease in rat kidney weights were not biologically meaningful, and the weights were well within the normal range of kidney weights for control animals. It had no reservations about recommending the authorization of MON863 (Seralini *et al*, 2011). In June 2005http://en.wikipedia.org/wiki/Genetically_modified_food_controversies - cite_note-44 German court released the original study by Monsanto (Statement of Court, 2005).

Conclusion

Results obtained by comparison contribution of conventional and molecular breeding increase demonstrated that still conventional technologies have prestige. Higher molecular breeding contribution has been recorded in undeveloped countries because GM genotypes have higher yield before transformation and usually for the first time have been planted in this part of world. Many scientific groups are investigated GMO – originated foods and almost all agree that there is not drastic difference between food safety between foods produced from non - GM plant and varieties developed through conventional technology. Several cases when GM – plants have been found as dangerous for environment authors (particularly Monsanto and Pioneer) stopped to sell those materials. Results on negative effect on experimental animals and even several human cases USA- FDA did not find as convincing one. Even there are differences between GM and GMO - food regulations in Europe and USA many countries in Europe started to grow genetically modified plants. Highly processed foods, such as vegetable oils or breakfast cereals, most likely contain some tiny percentage of genetically-modified ingredients because the raw ingredients have been pooled into one processing stream from many different sources. Also, the ubiquity of soybean consumer derivatives as food additives in the modern American diet virtually ensures that all U.S. consumers have been exposed to GM food products. (http://vm.cfsan.fda.gov/%7Elrd/biocon)

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