Is GMO Safe?
(A Perspective of Plant Biotechnology in Korea)

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Abstract

1950-1960 년대의 녹색혁명은 1970년 Nobel 평화상수상자 Norman Borlaug가 주도했었다. 제1 녹색혁명은 지구상의 가장 큰 문제점중의 하나인 기아를 해결하는데 크게 일조하였다. 많은 사람들을 굶주림으로부터 해방시켰지만 굶주리는 사람보다 더 많은 사람들이 매일 태어나고 있고, 지구의 인구증가는 지금까지 계속되고 있다. 언제까지 인구증가가 계속될 것인지, 인구증가에 따른 식량자원의 증가도 비례할 것인지는 오래전부터 인류의 관심의 대상이 되어 왔고, 자연스럽게 지구의 기아를 해결하는 제2의 녹색혁명은 과학자들의 연구를 집중시키는 결과를 낳게 되었다.

1980 년대에 미국 Monsanto 회사에서 유전공학적으로 개발한 RoundUp-Ready 제초제저항성 및 Bt-살충농작물을 선보이면서 제2의 녹색혁명이 시작되었다고 볼 수 있겠다. 이렇게 제2의 녹색혁명은 유전공학에 의한 GMO 식물·작물에 의해 시작되었다. Monsanto 회사는 살충제 RoundUp 제초제 저항성 옥수수, 콩, 목화, Canola (유채꽃, rape seed) 등을 개발하여 이미 상업화 하였다. 1960년대 쌀의 녹색혁명도 유전적으로 벼 집이 짧은 품종에 의해 이루어졌다.

최근에 개발된 GMO "Golden Rice"는 비타민 A와 철분의 함량을 대폭 증대 시켜 세계 영양결핍 아동들의 건강과 시각을 향상시킬 것으로 기대되는데, "Golden Rice"는 제1회 금호국제과학상 수상자인 Potrykus (스위스공대) 교수가 개발하였다. 그러나 현재까지는 그 보급에 많은 장애물이 있다. 특히 GMO의 환경과 건강에 대한 안전성을 의심하는 사람들이 많다.

제2의 녹색혁명의 또 다른 분야는 식물의약 분야이다. GMO 개발에 적용되는 기술을 이용하면 taxol 같은 항암제, carotene 같은 항산화 영양제 등의 대량 생산이 가능해진다. 식물은 화학적 합성이 아주 까다로운 약제물질 등을 천연상태에서 합성하고 있기 때문이다. 또 식물은 lipoxygenase 효소계가 있어서 마치 천연물 석유제조공장과 같은 제조공정 capacity를 가지고 있다.

그러면 식물/식품 GMO는 안전한 것 인가? 아니, KBS의 한 사회자가 말했듯이, 그리고 많은 소비자들이 믿는 것 처럼 GMO는 위험한가? GMO에 대한 일반 사람들의 공포감은 Green Peace당원들 뿐만 아니라 일부 과학자들에 의해서도 조장되고 있다. 이러한 분위기 속에서 GMO에 의한 제2 녹색혁명은 Africa 대륙에서의 제1 녹색혁명이 지금도 지연되는 것과 같다고도 볼 수 있다. GMO의 환경에 대한 악영향은 과대 선전되어 있는 것이 아닌가? 마치 GMO가 화학비료, 농약제보다 더 위험하다고 믿는 사람들도 많다. 나는 이러한 GMO 공포증이 과학적으로 그리고 "Risk Assessment"의 견지에서 볼 때 그 근거가 희박 하다고 보여주는 몇 몇 실험 및 경험 사실들을 인용 하려 한다. 그리고 올바른 Risk Assessment야 말로 한국의 21세기 BT 산업을 경쟁력 있게 하고 국민 년 소득 2만불 달성에 중요한 기여를 하게 될 것이라고 생각한다. 한국은 농토가 적고 천연자원이 빈약하다. GMO는 21세기의 생존 경쟁 산업이다. 제2의 녹색혁명은 얼마든지 가능하며, 한국은 부족한 농토와 빈약한 자원에도 불구하고 능력 있는 인적자원이 풍부하여 GMO 개발 연구에 국제적 경쟁력을 키울 수 있다. 그러나 GMO에 대한 논쟁만 하고 있으면 이미 때가 늦는다. 미국은 이미 GMO-BT 시장을 거의 완전 독점 했으며, 타국에서의 논쟁과 불합리적으로 엄격한 GMO관련 규정을 조장하고 환영 한다.

Is GMO Safe

The title of this talk concerns two aspects of the safety issue on GMO (genetically modified organisms), namely (i) the effects of GMO crops on the natural environment and (ii) the safety of GMO food derived from the GMO crops. Both environmental preservation and food safety are of utmost importance to us all. Yet, we also realize that nothing is absolutely safe. Opponents say "all GMO are bad." They are those who reject GMO in any form or shape because GMO is not absolutely safe. In fact, most consumers and environmental conservationists believe the evidence against GMO safety is stronger than for it. This "belief" is often fortified by the mass media not necessarily well based on scientific facts. I recently surveyed the audience after my presentation of a talk on GMO safety. One respondent commented on a written questionnaire form that news media coverage gave her strong conviction against GMO.

Today, I have the pleasure of speaking to you the well informed plant biotechnologists and share my point of view with you that GMO safety must be discussed in terms of relative risk assessment, compared to non-GMO alternatives, in solving ever-increasing global population problem and for economic survival as a developed country in the competitive 21st century. At the beginning of 20th century, world population was 1,890,000,000. Now it is 6,383,500,000 and growing! The United Nations reported that 840 million people suffered from hunger and starvation in 2002, and the global starvation figure has been increasing by ca. 25 million annually. Many of the hungry people are children who die or never reach their full intellectual and physical potential due to malnutrition and starvation. Many in plant biotechnology including those of us affiliated with the Korean Society of Plant Biotechnology believe that innovations in GMO agrobiotechnology (plant biotechnology, pBT) can go a long way to save the hungry children of the world.

First, I will briefly describe the nature of GMO agrobiotechnology and later, its status in Korea. What is a GMO? The so-called genetically modified organisms can be obtained by (i) classical breeding in which hundreds of genes are altered or introduced from one type of cultivars to another, (ii) mutation of a wild type plant with X-ray, (-ray or chemical mutagens, etc., which usually alters a single gene, and of course (iii) by genetic engineering, "artificially" altering usually one gene. More than one gene can now be altered or introduced by genetic engineering (pyramiding). Historically, Hess (1969) coated the germinating seeds of white petunia with total leaf DNA from red petunia and obtained 0.06% "genetically transformed" or "genetically modified" white flower with red pigment. This experiment probably was the first genetic engineering applied to a plant, "artificially" transforming white petunia to red petunia, most likely introducing one pigment-synthesizing gene from the red to the white petunia. It is ironical that the GMO opponents do not voice their objections to the GMO generated by the two classical and "artificial" methods (i and ii, respectively), but they do express, sometimes raucously and even violently, their rejection of GMO that also result from a single gene mutation/ introduction by genetic engineering.

It is of course extremely important that GMO in the form of transgenic crop plants and the food derived from them are safe for environment/ecology and human/animal consumption, respectively. In assessing the ecological and environmental safety of GMO crops, comparative and relative risk assessments of the transgenes are more rationale than an absolute risk assessment approach. Kok and Kuiper ("Comparative safety assessment for biotech crops", *Trends in Biotechnology,* 21: No. 10, 2003) suggested that the comparative safety assessment approach avoids misinterpretations that may arise from an absolute safety assessment approach. In this vein, let us take a look at the safety issue in GMO agrobiotechnology by reviewing the pre-GMO conventional agriculture exemplified by Green Revolution.

The 1970 Nobel Peace Laureate Norman Borlaug led the way to the 50's-60's Green Revolution based on the breeding technology and the *effective* use of agrochemicals including synthetic fertilizers. The Green Revolution saved millions of people around the world, especially in under-developed areas of the Globe, from starvation. Rachel Carson, the notorious author of "Silent Spring" (1962), courageously and eloquently warned the public about the long-term effects of *profligate* use of chemical pesticides on human health and the environment. The Green Revolution saved (and still saving) millions of starving people, and yet it adversely affected public health and the environment. Efforts are continuing to manufacture more environmentally friendly and biologically less toxic agrochemicals to minimize their now well-documented risks, while agrochemicals are being applied under better control and management requirements to protect human health and biodiversity in the environment. The pBT aims to achieve higher harvest yields in the post-Green Revolution era, while at the same time enabling the farmers to minimize the use of agrochemicals. This is the second Green Revolution. For any revolution, political or technological, there bound to be resisting forces, and GMO agrobiotechnology is no exception. As for any resistance movement, the GMO opponents are often unilaterally committed to their point of view and uncompromising.

The first Green Revolution began with the development of high-yield crops such as wheat and corn, and later rice, with significantly shorter stems and straws as compared to the pre-Green Revolution wild type crops. The second Green Revolution just introduced in the early 90's started with first generation of genetically engineered herbicide-resistant RoundUp Ready and Bt-insecticidal crops including soybean, corn, cotton and canola developed by Monsanto Company. Plant biotechnologists now believe that agrobiotechnology offers some of the most promising technologies for the enhanced quality of life and for more palpable environment in the 21st century and beyond. Innovations in agrobiotechnology are producing second generation of GMO crops with such traits as virus-resistance, nematode-resistance, fungal resistance, insect resistance, nutrient enrichment, oil and starch production. We will witness the third generation of new GMO that are higher yielding, stress tolerant (vs. cold, drought and salt), longer shelf-life, better digestible, vitamin/long chain/omega-3 fatty acid enriched, and so forth. Bioplastics- and colorant- and bioenergy-producing crops are also forthcoming. As of 2003, more than forty different GMO crops including 17 herbicide resistant, 3 virus resistant, 13 Bt-toxin insecticidal, 2 male sterile, 4 delayed ripening, 2 thick-skinned and 2 altered fatty acid crops are allowed in the US food supply. The forty GMO crops are chicory (1), corn (14), cotton (5), flax (1), papaya (1), potato (3), canola (3), soybean (3), squash (2), sugar beet (2) and tomato (5). Some are commercially more successful (eg., corn and soybean) than others. However, none of these GMO crops are being produced and marketed in Korea. So, we are not one of competitive GMO-producing countries in the world today. Without concerted efforts of researchers and the support of the government, Korea likely remains an under-developed pBT country.

A second Green Revolution has just begun, slowly but surely! Slowly, because the public at large is reluctant to accept GMO, some environmentalist objectors are powerful, and the regulatory procedures and protocols including Cartagena Protocol on Biosafety of LMO's [adopted in 2000 and entered into force on September 11, 2003] are stringent and tedious. Surely, because by year 2003 ten countries are now growing 50,000 hectares or more of GMO crops and the USA alone grew 43 million hectares, accounting for 63% of global total and with an average annual increase of GMO acreage at a double-digit pace since 1996. Global sales of GMO seeds continue to grow at the same rapid pace. The 2001 sales estimate is at ca. $4 billion; the 2003 estimate is up from the 2001 estimate by ca. $ 1 billion. Don't these statistics alone say something about positive impacts of the GMO's on the environment as well as on human health, at least when assessed relative to the agrochemicals of the first Green Revolution?

On the basis of careful assessment of GMO safety, the United States General Accounting Office concluded that GMO food is as safe as non-GMO food (www.gao.gov/new.items, www.whybiotech. com). The FDA of the United States and the FSA of the United Kingdom issued similar assessments. A British scientific panel stated that GMO pose very low risks to human health. Professor Stephen Taylor, an expert food scientist, asserts that GMO foods in the US food supply system passed stringent safety requirements to meet FDA approval (private communication). For more information about the safety of GMO food, you may visit website www.iol.co.za.

It should be noted that the US consumers have been exposed to GMO food and have been consuming them for a period of some 8 to 10 years, with the remarkable records of no serious safety alarms or incidents. How about the effects of LMO (Living Modified Organisms) on the environmental biodiversity? Here, conclusions are less definitive and controversial. None-the-less, I would say the available data and scientific rationale indicate no alarming forecasts on the safety of LMO as far as biodiversity is concerned, especially when their risks and the safety concerns are assessed relative to those posed by agrochemicals.

As early as 1995, the US Environmental Protection Agency (EPA) concluded that "the Agency can foresee no unreasonable adverse effects to humans, non-target organisms, or to the environment .....(from the use of Bt varieties of corn)." Losey et al. (Nature, 1999) observed reduced survival of Monarch butterfly larvae feeding on milkweed dusted with Bt-corn pollen. This is not surprising. At such "high" concentrations, the pollen is likely to affect larvae of any organisms in the vicinity of the Bt-corn field. Several universities in the United States, Canada and Germany conducted research on the effects of Bt-corn pollen on the butterfly larvae since 1999. Their conclusions can be best described as either conflicting or inconclusive (Felke et al., 2001; Hansen et al., 2000; Stanley-Horn et al., 2001 versus Hellmich et al.. 2001; Wraight et al., 2000; Zangerl et al., 2001). Researchers agreed that there was some level of risk to non-target butterflies, but disagreed about how great the risk was. In fact, many factors other than the Bt-corn pollen such as host specificity, overall habitat quality and loss, migratory behavior, insecticide impacts, predation pressure, etc, are probably more critical in affecting populations of Monarch butterflies over the past decades. Science advances. Innovations in plant biotechnology provide effective ways to minimize whatever risk there is with the Bt-corn or any other GMO crop.

A recent study demonstrated that transgenes in genetically engineered sunflowers had no major evolutionary dynamic effect on biodiversity of the environment (www.ish.yt.edu/news/2003/new). Contrary to the expectations of both GMO protagonists and opponents, targeted insect pests have developed little or no resistance to the Bt-toxin of the transgenic corns planted in the field. Thus, widespread commercial use of the GMO crops has not triggered the expected Bt resistance. Tabashnik (*ASM News*, 69: No. 10, 484-485, 2003) stated that "more than 500 species of insect have evolved resistance to one or more of conventional insecticides. So far, the track record for Bt is better. In the field, only one pest, the diamondback moth, has evolved resistance to Bt sprays, and none has evolved resistance to Bt crops." This means that the Bt-corn remains effective in the field over many years. Perhaps it's not surprising that the CSIRO/Australia reported a 75% reduction in pesticide use as a result of cultivating GMO cotton. It goes without saying that the reduced use of chemical pesticides is profitable for the farmers and safer for biodiversity of the environment.

As a photobiologist-turned plant biotechnologist, to me fireflies are one of the most fascinating organisms on Earth. They convert chemical energy to light energy in the bioluminescence emission. Sadly, they are nearly extinct from the Korean wild, most probably due to the profligate use of agrochemicals in Korea. GMO crops offer not only the platform for sustainable agriculture for the farmers, but also improve the quality of environment, hopefully bringing the fireflies back to the wild for the pleasure of seeing their flashing light in hot summer night.

Recently, the president of the Royal Society-UK published what is now acclaimed to be the Farm Scale Evaluation (FSE) of herbicide-tolerant GMO corn, canola and sugar beet planted in huge scale in the UK farm. The FSE assessed the long-term effects of the GMO on farmland biodiversity. Here again, results are inconclusive. Corn actually had a favorable effect on biodiversity, whereas sugar beet and canola showed a negative impact. An aspect of the FSE results that are not well publicized in the news media but extremely significant was that the three GMO crops in the FSE tests all had reduced amounts of spraying, compared with the non-GMO crops. The reduced spraying is certainly good for the environment. Could it account for the FSE's inconclusive results? One thing is for sure, however. To proclaim "all GMO are bad" is scientifically wrong, although to say "all GMO are good" for the environment may be a gross oversimplification. However, it is worth emphasizing here that the overall quality of environment will be more effectively managed through GMO agrobiotechnology than through agrochemicals-based conventional agriculture.

Finally, where does/will Korea stand in the worldwide pBT wave? As I mentioned earlier, Korea remains one of a few non-GMO countries of the world. To achieve the national goal of $20,000 GDP by 2010, we understand the importance of cutting edge technologies such as BT, ET, IT, NT, etc, for competitive economic development. Most countries consider pBT essential as one of the critical areas of BT for the development of economically sustainable agriculture. For the same reason, pBT should be included among the top priority technologies for ROK-governmental support. Failure to do so now, for the public's exaggerated fear of GMO, is tantamount to irreversibly falling from the rapidly advancing pBT bandwagon.

Recommended Readings

1. 작물유전체기능연구사업단 (단장 최양도), 식탁위의 생명공학 (2002)
2. U. Sonnewald, "Plant biotechnology: From basic science to industrial applications", *J. Plant Physiol.* 160: 723-725 (2003).
3. R. Emrich, "Discussion of current status of commercialization of plant biotechnology in the global marketplace", *J. Plant Physiol.* 160: 727-734 (2003).
4. "Global status of commercialized transgenic crops: 2003," www.isaaa.org/kc (January 14, 2004)
5. "The farm scale evaluations of spring-sown genetically modified crops", *Phil. Trans.: Biol. Sci.* B, 358: No. 1439, 2003.