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Trends in Genetic Modified(GM) Plants and Foods

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2.1 Introduction

Genetic Modified (GM) plants and foods are expected to contribute to solving various problems such as food crises and environmental concerns. In particular, GM plants with useful properties are on the verge of commercialization thanks to the recent dramatic developments in genome studies. Under these circumstances, expectations are running high across the world for the development of GM plants.

On the other hand, the majority of Japanese people are not necessarily longing for the early commercialization of GM plants and foods. Underlying this situation is a stable supply of food supported by domestic production and imports, as well as lingering concerns among consumers about the safety of GM foods.

Over the medium and long term, however, the following can be justified:

- The government is responsible for assuring its citizens of a stable supply of food under the adverse circumstances where demand for food is increasing worldwide in response to the expanding population, and food production is expected to decline due to global warming and other factors.
- While Japan is increasingly becoming a nation of old people, technological innovation in food is expected to play a major role in increasing healthy life expectancy, and creating a vital aging society.

It is thus very important to push forward with Research and Development(R&D) of GM plants and foods as a national policy.

In order to carry out a series of basic plans for science and technology, a general meeting for science and technology recently mapped out “The 2002 Guidelines for the Distribution of Budget and Resources to Science and Technology.” of priority areas in life sciences, the guidelines place particular emphasis on R&D of GM plants and foods as follows:

- Preventive and therapeutic technology that contributes to creating a vital aging society: improve preventive measures through development of functional foods.
- Technology necessary for food, the environment, and production of goods: promote genome analysis of plants and microorganisms, and make use of the accomplishments of the analysis in order to improve the production process of useful substances, and to develop various quality crops, environmental-stress-resistant crops, and biodegradable technology for environmental pollutants.

This article addresses measures for promoting R&D and the safety of GM plants in response to the current circumstances surrounding GM plants in Japan.

2.2 The Present Situation of GM Plants

2.2.1 GM Plants Developed in the World

Chart 1 shows GM plants up to now developed in the world.

In 2000, the total growing area of GM plants stood at 40 million ha, 50% of which was for herbicide-resistant soybean, and 30% for insect-resistant corn. As of 2000, 13 countries have tried commercial plantation of GM plants, and the growing area is expanding with the U.S. commanding about a 70% share.

2.2.2 Plantation of GM plants and GM Foods in Japan

Chart 2 shows the GM plants, plantation of which is approved, and the safety of which as food has been verified in Japan.

However, small-scale plantation of carnation has been the only commercial production of GM plants in Japan. The Plant Protection Law bans imports of fresh potato and sugar beet, while they can be imported in the form of processed food.

2.2.3 Classification of GM Plants by Objective

GM plants can be classified into several groups by objective, as shown in Chart 3.

In general, GM plants have been developed primarily for ensuring stable yields of crops by reducing damages caused by herbicides and insects – e.g., insect-resistant plants incorporated with the genes of insect-control protein isolated

Chart 1: GM Plants Developed in the World

Designed Properties	Crops
Herbicide-Resistant	Soybean, Cole, Corn, Cotton, Rice, Wheat, Sugar beet, Potato, Tomato, Flax, Poplar
Insect-Resistant	Corn, Cotton, Soybean, Potato, Cole, Rice, Tomato, Eggplant, Apple, Tobacco, Sugar Cane
Herbicide- Insect -Resistant	Corn, Cotton
Disease-Resistant	Papaya, Squash, Rice, Wheat, Carrot, Eggplant, Tomato, Potato, Cucumber, Watermelon, Onion, Strawberry, Melon, Sweet Potato, Sugar Cane, Sunflower, Tobacco, Grape, Apple, Cole, Soybean
Improved Productivity	Corn, Rice, Wheat, Cole, Soybean, Tomato
Poor-Environment-Resistant	Tomato, Carnation, Wheat, Cotton
Long shelf Life	Tomato, Carnation, Strawberry, Melon, Petunia
Improved Ingredients or Functions	Oleic-Acid-Rich Soybean, Lauric-Acid-Rich Cole, Vitamin-Rich Rice (containing beta carotene), Rice Containing Engineered Protein, Soybean Containing Engineered Protein, Amino-Acid-Rich Wheat (methionine), Potato Containing Engineered Starch (low in amylose), Cotton Containing Engineered Fiber, New Color Carnation

Source: The Agriculture, Forestry and Fisheries Research Council

Chart 2: Plantation of GM plants and GM Foods in Japan (as of July 23, 2001)

Plants	Added Properties	
	Those Proved to be Safe for Plantation in Fields	Those Proved to be Safe as Food
Adzuki bean	Insect-Resistant	
Rice	Virus-Resistant, Low Allergen, Low Protein (suited for sake brewing), Low Glutelin, Herbicide-Resistant	
Carnation	Long shelf Life, Different Colors	
Cauliflower	Herbicide-Resistant, Male Sterility	
Cucumber	Gray-Mold-Resistant	
Potato		Insect-Resistant
Soybean	Herbicide Resistant	Herbicide-Resistant, Oleic-Acid-Rich
Sugar beet		Herbicide-Resistant
Maize (Corn)	Herbicide Resistant, Insect-Resistant	Herbicide Resistant, Insect-Resistant
Tomato	Virus-Resistant, Pectin-Rich, Long shelf Life	
Torenia	Different Colors	
Cole (Rapeseed)	Herbicide-Resistant	Herbicide-Resistant, Male Sterility, Improved Fertility
Broccoli	Herbicide-Resistant, Male Sterility	
Petunia	Virus-Resistant	
Melon	Virus-Resistant	
Cotton		Insect-Resistant, Herbicide-Resistant

Source: Home Page of the Ministry of Agriculture, Forestry and Fisheries of Japan ; Prepared by the Science and Technology Foresight Center from Bacillus thuringiensis (Bt); plants that are resistant to herbicides such as glyphosate agents; and plants that are resistant to diseases caused by viruses. These GM plants, which are referred to as "the first-generation GM plants," benefit producers by saving labor on such things as crop-dusting.

In the meantime, development of the second-generation GM plants, elements or taste of which are modified, is on the rise. These are high value-added plants in terms of food, and hence they bring great benefits to consumers – e.g., oleic-acid-rich soybean having the properties of reducing blood-cholesterol levels, and low-allergen rice that inhibits production of allergens.

Some of the next-generation GM plants are intended for contributing to developing countries where good health is hard to come by and the distribution of pharmaceuticals is virtually non-existent. Specifically, some GM plants are designed to function as pharmaceuticals – e.g., plants with properties of oral vaccines, and plants rich in beta-carotene, a base element of vitamin A, which prevents visual impairment.

Other plants having the same properties as those

Chart 3: Classification of GM Plants by Objective

Crops	Added Properties
(1) Plants that Benefit Producers	Herbicide-Resistant Plants, Insect-Resistant Plants, Virus-Resistant Plants, High-Yielding Plants, Salt-Resistant Plants, Drought-Resistant Plants, etc.
(2) Plants that Benefit Consumers	High-Quality Plants (Oleic-Acid-Rich Plants, etc.), Tasty Plants, Low-Priced Plants, etc.
(3) Plants for Maintaining Health and Treating Diseases in Developing Countries	Vitamin-A-Rich Plants, Plants Producing Live Vaccines, Plants Producing Diagnostics, etc.
(4) Plants for Rehabilitating the Environment	Plants Absorbing or Decomposing Heavy Metals, NOx and SOx, etc.
(5) Others	Plants Generating Clean Energy, etc.

Source: Hiroshi Kamada, Tsukuba University

Chart 4: The 7TH Technology Foresight Survey: Technological Challenges to GM Plants

Technological Challenges	To be Commercialized by:
Development of an assessment method that is understood by consumers and reviews the safety of GM crops from food and environmental perspectives.	2011
Development of foods that prevents degradation in the anti-oxidant function, cerebral function, and mastication function, all of which are characteristics of the aged, thereby supporting a healthy aging society.	2012
Widespread proliferation of GM crops with improved yields, disease resistance, and freezeresistance in Japan.	2013
Development of GM foods containing functional elements that prevent hypercholesterolemia, high blood pressure, hay fever, etc.	2013
Commercialization of low-temperature-resistant plants with molecular mechanisms transmitting information (from reception of external information such as low temperatures to expression of properties) being determined.	2014
Social recognition and widespread proliferation of GM crops that can be cultivated without agrochemicals.	2015
Development of commercial species of needle-leaf trees with useful properties (e.g., cedar producing no pollen) through applications of new technologies to forest tree breeding (e.g., gene manipulation and cell fusion).	2015
Widespread proliferation of functional foods that prevent life-style related diseases in accordance with the constitutional tendencies of individuals.	2015
Commercialization of GM plants and microorganisms that can remove environmental pollutants such as NOx.	2018
Commercialization of breeding technology for drought-resistant and salt-resistant plants in order to stop desertification.	2018
Development of crops having the properties of fixing nitrogen in the air and phosphoric acid in the soil (environmental conservation technology for reducing fertilizer application).	2018
Commercialization of plants for fuel that accumulate high concentrations of hydrocarbons.	2019

Source: The Science and Technology Foresight Center of the first-generation GM plants are environmental stress-resistant plants, which ensure a certain amount of yields even in an unfavorable environment for cultivation (climate, soil, etc.). As for non-food applications, development of plants that can rehabilitate or purify the environment, or generate energy (plants producing fuel alcohol, etc.) is taking place.

However, commercialized items are still limited to part of the first-generation and the second-generation GM plants. The National Institute of Science and Technology Policy (NISTEP) foresights that GM plants will be developed and commercialized as shown in Chart 4.

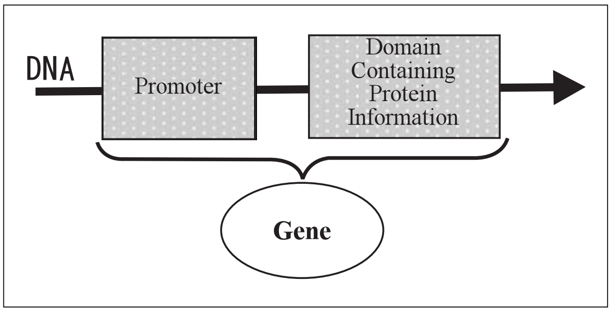
2.3 Current Trends in R&D in Japan

2.3.1 Technology for Creating GM Plants

(1) The Structure of DNA

In general, organisms transmit their gene information by DNA (deoxyribonucleic acid). There is a domain called "gene" in part of the base sequence of DNA, and this domain is comprised of a promoter, a domain controlling gene expression, and a domain containing protein information (see Chart 5). While the base sequence of each domain containing protein information is common to each corresponding protein among the same species of organisms, promoters controlling gene expression vary with the species of organisms, expression periods, expression sites, and the amount of expression. This is why each organism and site creates different types of protein. It is thus possible to create a specific type of protein in a site of a target organism by combining promoters and domains containing the proper protein information.

Chart 5: Structure of DNA



Source: The Science and Technology Foresight Center

(2) Genetic Modification Technology for plants

The genetic modification technology for plants can be broadly categorized into gene transfer technology, gene expression regulation technology, and Genetic Modified Organisms(GMO) screening technology.

①Gene Transfer Technology (technology for transferring target genes to plant cells)

Gene transfer technology can be typified by the "Agrobacterium-mediated Transformation"(a method where useful genes are transferred to plant cells by means of the infectivity of soil bacteria to which those useful genes are transferred), and the "Particle Bombardment"(a method where useful genes adhered to fine gold particles, etc., is driven into plant cells at supersonic speeds). These two methods are practiced worldwide.

Unlike animal cells, however, plant cells are covered with cell walls and are relatively small – a feature that makes gene manipulation more difficult. Moreover, gene transfer is extremely difficult for some species of plants. Efficient technology for transferring genes to plant cells is thus required. As for development of gene transfer technology in Japan, a project subsidized by Bio-oriented Technology Research Advancement Institution (BRAIN), and led by the engineering research course of the graduate school at Osaka University, has developed technology for piercing a fine hole in a plant cell wall through the use of short-wavelength pulse laser beams. This technology is expected to develop into chromosome manipulation by mega base unit and direct gene transfer into organelles.

②Gene Expression Regulation Technology (technology for regulating the gene expression characteristic of each gene)

In general, promoters regulate gene expression, and promoters that express genes in specific parts of plants are being identified and isolated.

Technology for controlling the functions of specific genes is typified by the "Antisense Method "(a method where the expression of target genes are controlled by expressing genes that have sequences complementary to those of the target genes). In addition, the "Co-suppression Method" is used for creating oleic-acid-rich soybean (a method that utilizes the phenomenon that the expression of target genes is considerably regulated when the target genes themselves are transferred to plant cells).

③GMO Screening Technology (technology for screening GM plant cells)

In screening GMO, antibiotic-resistant genes of microorganisms, along with target genes, can be transferred to plant cells as an indicator. Nippon Paper Industries, however, developed an alternative technology, namely the "MAT Vector System", because GM foods containing antibiotic-resistant genes of microorganisms may arouse concern among consumers. In addition to target genes, this method transfers genes inducing morphogenetic abnormalities; GM cells are visually screened out, and those genes inducing morphogenetic abnormalities are then removed from DNA.

Those gene transfer technologies mentioned above are based on the premise that target genes are transferred to chromosomes on a random basis. On the other hand, homologous recombination is commonly used for transferring specific genes to designated places in genomes – i.e., target genes are modified, capitalizing on the phenomenon where recombination takes place among DNA, the sequences of which are identical with each other. The establishment of this technology is expected to lead to the creation of useful crops by regulating the functions of specific genes, and more detailed analysis of gene functions. In particular, the technology is most needed for higher plants. Homologous recombination can be applied to Physcomitrella patens, a kind of moss, and this particular technology is being improved for applications for higher plants. However, there are many hurdles to surmount.

2.3.2 Patents Relevant to Genetic Modification Technology

Of the technologies necessary for the development of GM plants described in (2) of the section above, all the useful technologies are protected by patents. Research institutes and private enterprises engaged in the development of GM plants on a commercial basis should thus be licensed under relevant patents belonging to other research institutes, etc. Chart 6 shows the major patents in this particular field.

Foreign companies (e.g., nursery companies, agrochemical companies, etc.) hold major patents such as those for: the "Agrobacterium-mediated Transformation" and the "Binary Vector Method", both of which are indispensable for commercialization-oriented R&D; gene transfer methods such as the "Particle Bombardment"; methods for regulating expression of transferred genes (promoters, etc.); and methods for screening antibiotic-resistant genes, etc. Most of these patents were filed in the middle of the 1980s, all of which will be off-patent within the next few years. It is thus very important to take advantage of these opportunities in order to improve existing technologies, foster groundbreaking studies that may lead to the development of advanced technologies such as homologous recombination, and explore useful genes.

In Japan, several methods for transferring genes to the cells of monocotyledonous plants (rice, etc.) have been developed; the application of gene transfer technology to these plants using "Agrobacterium-mediated Transformation" remains difficult. Moreover, some epoch-making screening methods such as the "MAT Vector System" mentioned earlier have been developed as well.

Therefore, as far as the existing technologies are concerned, development of GM plants on a commercial basis is expected to become easier by making full use of practical domestic patents and technologies whose patents will expire shortly. For instance, joint researches among universities that isolate useful genes, public research institutes that hold patents for gene transfer technology and the like, and municipal experimental research institutes that actually develop new varieties would facilitate development of GM plants on a commercial basis.

Moreover, participation of private enterprises is indispensable for commercializing basic researches such as researches on the plant genome. For this reason, there is a need to promote R&D among non-food industries in order to stimulate R&D of private enterprises.

Specifically, priority areas in R&D should be broadened (e.g., GM plants producing substances such as industrial materials), so that private enterprises in various sectors can make inroads. Through these efforts, R&D systems for common basic technologies can be strengthened.

2.3.3 The Present Situation of and Future Approaches to R&D in Japan

Public research institutes and universities in Japan have been relatively active in pursuing basic researches in gene expression, as well as in the

Chart 6: Foreign Technology and Domestic Alternative Technology Relevant to the Development of GM Crops

Technology	Foreign Technology		Domestic Alternative Technology, etc.	
	Designation	Patent Holder (Expiration Year)	Designation	Patent Holders / Developers (Expiration Year)
Methods for Transferring Genes	Agrobacterium-mediated Transformation	Max-Planck Institute (2004)	Genetic Transformation of Monocotyledonous Plants Using Agrobacterium	Japan Tobacco (2013)
			Ultra Rapid Genetic Transformation of Monocotyledonous Plants	National Institute of Agrobiological Sciences (2019)
	Binary Vector	Mogen (Astra Zeneca) (2004)		
	Electroporation-mediated Transformation	Ciba-Geigy (2005)	Polycation-mediated Transformation	National Agriculture Research Center (2014)
	Genetic Transformation of Protoplast of Plants (PEG Method)	Novartis (2005)		
	Particle Bombardment	DuPont (2011) Agracetus (2007)	Particle Bombardment	Rehbock Commerce and Industry (2012)
Methods for Regulating the Expression of Transferred Genes	CaMV35S	Monsanto (2004)	PR1 Promoter	No Patent Applicable National Institute of Agrobiological Sciences
	Ubiquitin Promoter	Mycogen Plant Science (applied for on May 17, 1989, unregistered)	Retrotransposon Promoter	No Patent Applicable National Institute of Agrobiological Sciences
			LHCP II Promoter (Photo Synthesis-Related Genes)	National Institute of Agrobiological Sciences (2010)
			Soybean Green Spot Virus Promoter	National Institute of Agrobiological Sciences (2009)
	Basic Patent for Antisense Technology	State University of New York (2004) Zeneca (2007)		
Methods for Screening GMO	Kanamycin-Resistant Genes	Monsanto (2004)	MAT Vector System	Nippon Paper Industries (2015)
	Hygromycin-Resistant Genes	Eli Lilly and Company (2004)		

Source: The Agriculture, Forestry and Fisheries Research Council exploration of useful genes through functional analyses of plant genes and the collection of various genes from microorganisms and other organisms. However, there have not been many cases where these basic researches lead to the development of GM plants.

As rice is the chief staple diet in Japan, national research institutes place emphasis on R&D of rice. In addition to rice, meanwhile, municipal experimental research institutes have been conducting researches on their specialty crops. The recent trend, however, has been to shift from crops to flowers and ornamental plants – commodities gaining wider market acceptance as GM plants. Considering the poor marketability of GM foods in the future, nursery companies and food companies alike are switching their R&D targets from crops to flowers and ornamental plants, exploring new colors and long shelf life. Moreover, a growing number of companies are pulling out of the GM-food business for fear that engaging in the development of GM foods may blemish their corporate image.

That said, ensuring a stable supply of quality food and extending people's healthy life expectancy continue to be critical issues for the government. R&D of GM plants and foods, both of which are expected to contribute to solving these issues, should thus be pursued in the future. For this reason, the government needs to consider how it should promote R&D of GM plants and foods.

The following are the possible approaches to R&D with domestic production in view:

i) Development of disease-resistant, insect-resistant, and high-yielding crops that contribute to stable food production
ii) Development of quality crops (eating quality, processability, etc.) that can compete against imported crops
iii) Development of new crops (functional foods) with particular emphasis on functional elements

As an approach to R&D efforts with international cooperation in view (e.g., solution of the food problem in developing countries), the following can be suggested in addition to item i) mentioned above:

iv) Development of crops having properties such as environmental-stress-resistance (drought-resistance, salt-resistance, etc.)

In addition to R&D intended for crops, development of plants with the aim of solving environmental concerns and energy problems is also important.

In creating a market for GM plants step by step, it may be appropriate to start with the development and commercialization of GM plants having the functions of improving health and treating diseases – commodities that can be accepted by consumers with relative ease.

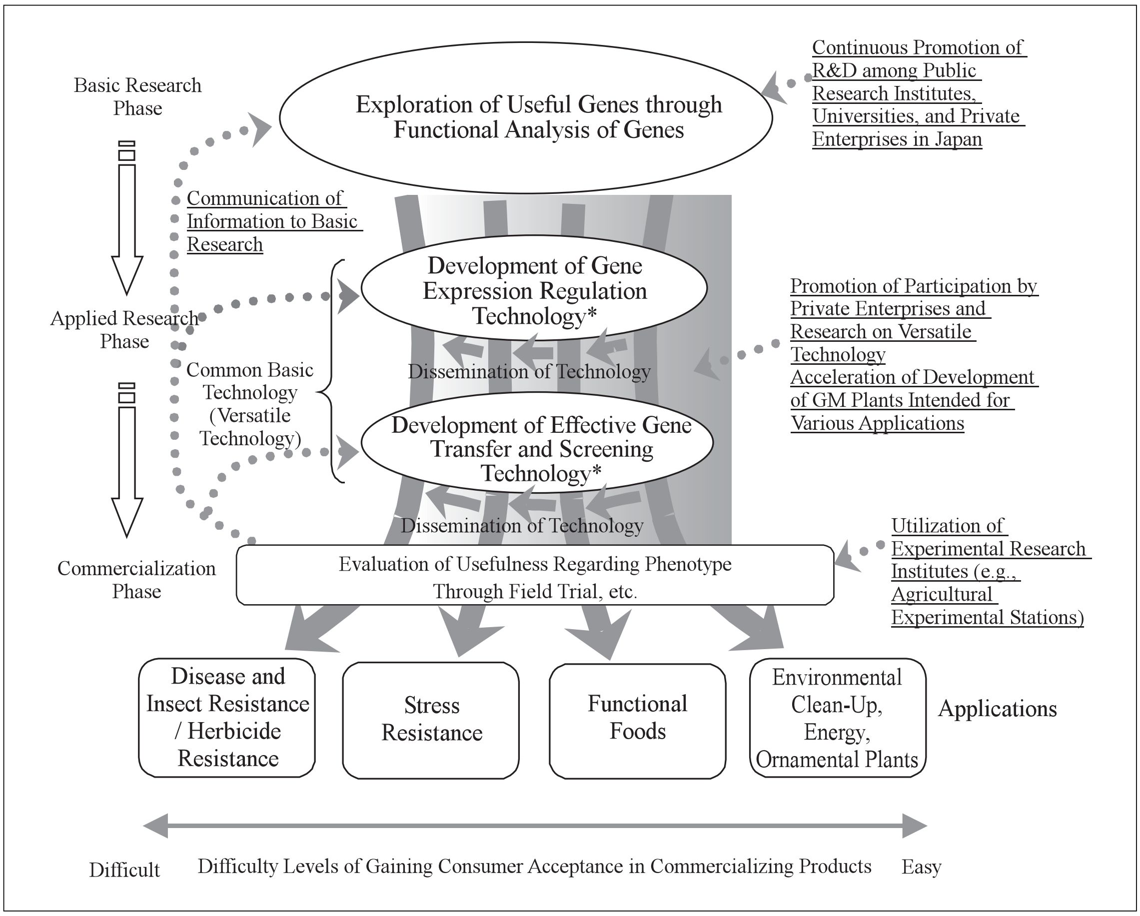
Thanks to rapidly progressing researches on the plant genome centered on rice, a growing number of useful genes that provide crops with designed properties are being identified and isolated; these accomplishments should immediately be linked with development of new varieties. To this end, there is a need to create a system through which GM plants, based on the accomplishments of genome researches, are developed and evaluated in a timely manner (e.g., a partnership between basic research institutes that carry out genome researches and field research institutes such as agricultural experimental stations that develop and evaluate GMO).

2.3.4 Measures for Promoting R&D in Japan

Chart 7 illustrates measures for promoting R&D in Japan. As mentioned earlier, national research institutes, universities, and part of private enterprises have been relatively active in pursuing basic researches in gene expression as well as in the exploration of useful genes through functional analyses of plant genes and the collection of various genes from microorganisms and other organisms. It is important to maintain this momentum by aggressively introducing state-of-the-art analysis technology such as bioinformatics and systems biology.

Versatile technologies such as gene expression regulation and gene transfer are the basis for developing GM plants, and hence they can be used for creating various GM plants – a feature that makes their patents extremely useful. To take a look at the recent trend in R&D efforts outside

Chart 7: Measures for Promoting R&D of GM Plants



* Advanced basic research in the field of molecular biology should be promoted in order to make a breakthrough in common basic technology - i.e., technologies for gene expression regulation, gene transfer, and screening.

Source: The Science and Technology Foresight Center

Japan, a growing number of private enterprises emphasize patent strategies in their R&D to develop these kinds of useful technologies.

The situation in Japan exhibits sharp contrast to this trend, as mentioned earlier: due in large part to consumer preferences for safer foods and corporate-image-related issues, private enterprises such as nursery companies and food companies are, and will be, facing difficulties in putting corporate resources into R&D of GM plants intended for foods (subsidizing these companies may not be an effective measure in view of the negative images inherent in GM plants).

In addition to promoting R&D efforts among national research institutes and universities, therefore, there is also a need to encourage private enterprises in various industrial sectors to participate in the development of GM plants (e.g., plants designed for environmental rehabilitation, energy production, and ornaments), thereby pursuing applied researches to establish common basic technology.

In Japan, it is rarely the case that GM plants developed in laboratories reach a field trial phase. Indeed, sufficient data on the utility and practicality of isolated genes have yet to be accumulated through field trials. With this as a backdrop, research functions at the demonstration phase should be strengthened in order to study the feasibility of GM plants that have been developed, evaluate the usefulness of possible applications, and gather applicable information for the benefit of basic researches.

2.4 Global Trend Towards the Assurance of Safety

2.4.1 Concepts of Safety in the World

There has been a lot of talk about the safety of GM plants and foods worldwide over the past several years. The following are the major concepts of safety widely practiced across the world:

— Substantial Equivalence
A concept that serves as a standard for evaluating the safety of food: GM foods are evaluated in comparison with conventional foods that have been up to now consumed safely.
— Traceability
A concept that traces and identifies every aspect of the processes for cultivating, producing, and handling foods.
— Familiarity
A concept that serves as a standard for evaluating current safety levels from an environmental perspective: appropriate safety levels are secured based on existing findings and experience.

OECD, WHO, CODEX, and the Conference of the Parties to the Biodiversity Treaty set forth international regulations and standards for GM plants and foods.
CODEX, to which 165 countries are participants, is currently discussing international standards for the labeling of GM foods. As for the evaluation of the safety of GM foods, a biotechnology special session chaired by Japan is discussing issues such as "the principle in risk analysis of biotechnology-derived foods" and "the guidelines for evaluating the safety of foods derived from GM plants." CODEX approved an interim report on these two issues in a meeting held in July 2001; the final report is now being prepared for presentation at a general meeting scheduled in 2003.
With regard to possible environmental impacts, the Conference of the Parties to Biodiversity Treaty, to which more than 130 countries including Japan are participants, adopted the "Cartagena Protocol on Biodiversity" in January 2000. As far as the first exports of GMO (e.g., items to be directly released into the environment such as seeds) are concerned, this protocol mandates that exporting countries provide importing countries with the necessary information regarding GMO to be exported; import and export procedures can be accomplished only after importing countries and exporting countries have agreed with each other.

2.4.2 Trends in the U.S. and EU

(1) The United States
EPA, USDA, and FDA regulate GM plants and foods in accordance with the "Coordinated Framework for the Regulation of Biotechnology," which was set forth in 1986. However, there are no legal restrictions on the labeling of GM foods.
Deregulation of GM foods, a trend that was once dominant in the U.S., began to lose momentum in about 1999 in response to changing consumer awareness. "The Food and Biotechnology Initiative," which was announced by the Executive Office of the President in May 2000, sets forth the guidelines for tightening regulations based on scientific grounds, and for providing consumers with information on foods and biotechnology. FDA also announced a draft of the guidelines in January 2001 for in-advance applications regarding GM crops and their labeling. New concepts such as identity preserved handling are likely to be adopted in the U.S.

(2) EU
EU regulates GM plants and foods based on Directive 220/90: Release of GMO into the Environment. Premarketing safety review and labeling are thus compulsory for GM foods. Any foods containing GM foods should indicate accordingly on labels, along with allergens and ethical issues. EU is now discussing the introduction of laws and regulations including the concept of traceability in a bid to revise Directive 220/90, the feasibility of which remains uncertain because of issues such as the limitations associated with scientific evaluation and traceability.

2.5 The Assurance of the Safety of GM Plants and Foods, and Communications with Consumers

2.5.1 The Administrative Framework for Assuring Safety

In Japan, the environmental impact of GMO plants and their safety as food are evaluated in line with international concepts such as familiarity and substantial equivalence mentioned earlier.

As for safety issues relevant to the environment, the Ministry of Education, Culture, Sports, Science and Technology sets the guidelines for the basic research phase (i) closed-system greenhouse experiment, ii) non-closed-system greenhouse experiment), and the Ministry of Agriculture, Forestry and Fisheries, the guidelines for the industrial application phase (iii) experiment in a simulated environment). Cultivation experiments are conducted following these three phases.

i) Closed-System Greenhouse Experiment

Experiments conducted in a closed glasshouse: basic characteristics of GM plants – whether or not transferred genes are passed on to later generations, or toxic substances are produced – are determined.

ii) Non-Closed-System Greenhouse Experiment

Experiments conducted in a glass-mesh-house exposed to the open air: characteristics of pollens and seeds, and influences on soil microorganism are determined in a greenhouse equipped with a concrete floor and meshes.

iii) Experiment in a Simulated Environment

Experiments conducted in an isolated field encircled by fences, and equipped with an incinerator and a washing place: expression of transferred genes, influences on other organisms, and influences of airborne pollens on the environment are determined.

For use of GM plants in food, the Ministry of Health, Labour and Welfare mandates safety reviews based on the Food Sanitation Law. As for applications to fodder, the Ministry of Agriculture, Forestry and Fisheries sets guidelines.

2.5.2 Environment Impact Assessment

Environmental impact of GM crops is determined based on "The Guidelines for Use of GMO in Agriculture, Forestry and Fisheries," which was set forth in line with framework concepts such as familiarity. Examination results of compliance with the guidelines and updated information on cultivation experiments are announced through the Ministry's homepage or other media in a timely manner.

In order to make environmental impact assessments absolute and universal, these guidelines incorporate every assessment item that is considered necessary based on scientific grounds. The assessment items are reviewed from time to time through additional experiments to reflect new scientific findings. A group led by the National Institute for Agro-Environmental Sciences takes charge of these environmental impact assessments.

It is necessary to accumulate Japan's own assessment data because the results of assessments conducted in other countries, the environment of which differs from that of Japan, cannot be applied as they are. It is also important to continue monitoring environmental impact over the long term, assuming that large-scale commercial plantation of various GM plants will take shape in Japan in the future. Environmental impact assessments involve a wide range of studies such as botany, ecology, microbiology, entomology, pedology, and meteorology. Partnership with researches in these fields should thus be strengthened.

2.5.3 The Assurance of the Safety of GM Plants as Food

(1) Safety Reviews

Safety reviews of GM foods became mandatory in April 2001. Production, import, and handling of GM foods without safety reviews were banned in accordance with the "Standards for Food and Food Additives," which is based on the Food Sanitation Law; any violation of this arrangement may result in penalties. The Pharmaceutical Affairs and Food Sanitation Council, which is made up of experts in relevant fields, reviews detailed information and data on safety assessments to be provided by developers of GM plants. Specific items to be assessed are: the safety of transferred genes; toxicity of protein produced by transferred genes; the presence or absence of allergens; probabilities of transferred genes contributing to the production of toxic substances; and probabilities of transferred genes changing the elements of subjects dramatically. The results of assessments are announced through the Ministry's homepage or other media such as official journals in a timely manner.

As in the case of environmental impact

assessments, the standards for safety reviews are based on the latest scientific findings; they should thus be revised from time to time as new findings such as those on the mechanisms of allergy developments accumulate in the future.

(2) Labeling and Monitoring Inspections

Proper indications on labels and arrangements such as monitoring inspections are mandated in Japan in order to ensure appropriate handling of GM foods based on safety reviews.

In April 2001, the Ministry of Agriculture, Forestry and Fisheries set forth "The Law Concerning Standardization and Proper Labeling of Agricultural and Forestry Products (JAS)," and mandated GM foods have indications of their ingredients on labels in order to support consumers in selecting GM foods. In view of ensuring public heath, the Ministry of Health, Labour and Welfare took the same measure based on the Food Sanitation Law.

Designated crops are soybeans, corn, potatoes, coles, cottonseeds, and processed foods made from these crops, containing residual modified DNA or its by-product protein (soybean- or corn-derived foods). These crops are broadly categorized into: i) GM foods produced, handled, and managed separately; ii) GM foods produced, handled, and managed together with other non-GM foods; and iii) Non-GM foods produced, handled, and managed separately. Category i) and category ii) need to be indicating accordingly on labels, while category iii) may follow the instructions on a voluntary basis (non-compulsory).

"Identity Preserved Handling System (IP Handling)" is a system where proper management of specific items such as non-GM crops throughout production, handling, and processing is guaranteed by documents, etc. Absence of this management can be termed "Non-IP Handling." It is difficult to prevent GM crops from being mixed into materials; the percentage of GM crops to materials should be less than 5%, according to the regulations in Japan. Although all GM crops currently on the market have been proved to be safe, IP Handling continues to be indispensable for supporting consumers in selecting commodities.

Monitoring inspection, on the other hand, are widely practiced by quarantine stations and municipalities in order to prevent unidentified GM foods from being distributed in the domestic market, and to verify proper labeling of GM foods. In order to unify inspection methods for detecting "GM foods without safety reviews," the Ministry of Health, Labour and Welfare issued Notification 158: Inspection Methods for Genetically Modified Food.

2.5.4 Communications with Consumers

While genetic manipulation technology and the development of GM plants continue to advance, concern is growing among consumers about the safety of food. There is thus a need to create a social consensus through sufficient communication with consumers.

The results of "The Consciousness Survey Regarding the Commercialization of GMO," which was carried out by the Society for Techno-innovation of Agriculture, Forestry and Fisheries (STAFF) as a project commissioned by the Ministry of Agriculture, Forestry and Fisheries, shows that more than 50% of both food manufactures and retailers believe that GM foods are not well accepted by consumers. The reasons mentioned by more than 80% of food manufacturers are: mass media is generating widespread concern among consumers; and public institutes are not publicizing the safety of GM foods in a sufficient manner. Administrative bodies and other related organizations should thus communicate with consumers aggressively.

In a bid to encourage citizens to participate in science and technology, and to meet their needs, STAFF held "The Consensus Conference on GM Crops" from July to November 2000 at the request of the Ministry of Agriculture, Forestry and Fisheries. A consensus conference is a meeting where non-specialist citizens discuss given topics based on advice from specialists in order to build a consensus on those topics. Specialists and administrative bodies should cooperate in continuing this kind of important approaches in the future.

Through a series of on-line forums, the Ministry of Economy, Trade and Industry is releasing the results of discussions about the next R&D programs, while widely soliciting opinions from viewers. Research topics on GM plants are addressed in "The Creation of Recycling Industrial Systems Based on Bio-functions," one of the themes of the forums.

In response to a growing demand for gene-splicing experiments at high schools and other educational establishments, the Ministry of Education, Culture, Sports, Science and Technology plans to institute "Recombinant DNA Experiments for Educational Purposes" exclusively for safe experimental subjects; the purpose is to disseminate knowledge and facilitate the understanding of gene splicing.

In addition to the approaches mentioned above, administrative bodies and municipalities are releasing the results of relevant safety tests through their homepages, preparing PR brochures, and holding various seminars. There is also a need to create a comprehensive database covering a variety of information accumulated at ministries and research institutes (e.g., research topics, cultivation status, safety assessments, test results, and information on researchers, seminars, consensus conferences, etc.), so that information required can be searched in a cyclopedic form.

2.6 Conclusion

As far as Japan's current approaches to R&D of GM plants and foods, and the assurance of their safety are concerned, the following issues surface as subjects to be addressed in the future:

- The establishment of common basic technology such as gene recombinant is indispensable for commercializing achievements of basic researches on the plant genome, etc. While private enterprises are expected to play a major role in establishing this kind of technology, the present situation is such that they are having a hard time participating in R&D because concern is growing among consumers about the safety of GM foods. One effective option offered at this time, therefore, is to encourage private enterprises in various industrial sectors to participate in the development of GM plants (e.g., plants designed for environmental rehabilitation, energy production, and ornaments), thereby pursuing applied researches to establish common basic technology.
- In commercializing GM foods, those provided with the properties of contributing to health and treatment of diseases should be developed first – i.e., socially important items that can be easily received in the market.
- Researches on safety reviews (e.g., researches on experimental medicine such as those on food allergies, and researches corresponding to new scientific findings on environmental impact) should be continued.
- A system to indicate safety levels on labels should be improved, and administrative bodies and other related parties should communicate actively with consumers in order to establish a social consensus.

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