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Rice Biotechnology

ISSUE: The application of molecular biology to rice plant breeding in the developing world. Will rice biotechnology meet the needs of poor farmers and contribute to sustainable agricultural food systems in the Third World?
IMPACT: Rice is the world's most important food crop, providing the major source of sustenance to over half the world's population. The farm population dependent on rice exceeds 1 billion people; the vast majority are poor farmers.
PARTICIPANTS: The U.S.-based Rockefeller Foundation has supported rice biotechnology worldwide totalling approximately $49 million (1985-1992); Japanese government.; Plantech Research Institute (Japan); Plant Genetic Systems (Belgium); Agracetus (USA).
ECONOMIC STAKES: Value of rice crop estimated at (US) $108,000,000,000 per annum.
WHEN: Transgenic rice plants are now being field tested; some predict marketing/distribution of genetically-engineered rice varieties by late-1990s.

Overview of Rice

- Rice is the world's most important food crop. Nearly half the world's population (concentrated particularly in East and Southeast Asia) depends on rice as the major source of nutritional calories.

- Rice in Asia is typically grown by poor farmers on less than one hectare, with little or no use of machinery. The annual rice crop provides a major portion of the total farm family income. The farm population dependent on rice as the major crop totals at least 1.1 billion people comprising 225 million families. The vast majority of rice farmers live at subsistence level.

- The region of original domestication of rice is generally considered as the arc extending from northeastern India across Myanmar, Thailand , Laos, and northern Vietnam to southern China. Today rice is cultivated on every continent except Antarctica.

- Most of the crop is used directly for human consumption. In fact, only 5% of the rice grown is used in processed foods, industrial products and alcoholic beverages. The vast majority of rice is consumed where it is grown. Of all major food crops, rice is the least mobile; only about 4% enters world trade.

- In the world as a whole, rice occupies one-tenth of the arable land. But in the majority of the Asian rice-growing countries, it occupies one-third or more of the total planted area.

- Worldwide, 26 leading rice-producing nations, account for 96% of global rice production. Eighteen of these countries are located within South, Southeast and East Asia. The 8 countries outside of the region (Brazil, USA, former Soviet Union, Egypt, Madagascar, Colombia, Iran, Nigeria) jointly produce less than 6% of the world's rice crop.

- From 1948 to 1986, the area planted to rice increased by 67%, the mean yield obtained from that area went up by 95%, and total production more than tripled.

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Sequel to the Green Revolution: The Application of Molecular Biology to Rice Plant Breeding in the Developing World

The U.S.-based Rockefeller Foundation, a primary investor in the Green Revolution, is currently the world's largest source of support for rice biotechnology research. In keeping with the Rockefeller Foundation's long-standing commitment to the promotion of science and technology as the route to improving food production and living conditions in the developing world, the Foundation launched "The International Program on Rice Biotechnology" in 1984. To date, the Foundation has spent approximately (US) $49 million on the rice biotechnology program worldwide.[1] This includes grants to 62 biotechnology institutes in the developing world and 130 fellowships to Third World scientists totalling (US) $18.8 million.[2] Approximately 65% of all Rockefeller grant funds to developing country institutions have gone to China and India. These two countries account for 56% of world rice production. In addition, the Rockefeller Foundation has provided grants totalling (US) $6.2 million to five International Agricultural Research Centres (IRRI, CIAT, ICGEB, IFPRI, ISNAR).

The objectives of the International Program on Rice Biotechnology are to assure that advanced biological technologies are developed for tropical rice, to help strengthen capacity of developing countries to conduct rice biotechnology research, and to increase rice production in developing countries for the benefit of low-income rice producers and consumers.

The Foundation's decision to focus on rice was the result of detailed analysis. Not only is rice by far the most important crop in the developing world, but in the early 1980s, it was a highly neglected crop with regard to biotechnology. In 1983, a Foundation survey revealed that there was not a single research program on molecular genetics of rice in North America or Europe. (The one exception in the developed world was Japan, where both private corporations and government research programs on rice pre-date Rockefeller's program.) As one British scientist put it, "There is little commercial interest in rice...profit cannot be made readily from a half-million poor farmers."[3]

The Rockefeller Foundation trustees made a 10-15 year commitment to the application of rice molecular biology in developing countries. After a period of only 7 years, the progress has been remarkable. Because of the Foundation's (US) $49 million commitment to rice biotechnology, rice has moved from a position of virtual neglect to one of premiere status in molecular biology. In less than one decade, progress in rice biotechnology has been more rapid than with any other cereal crop, and it is now considered a model plant for cereal research.

Green Revolution Re-visited?

Many NGOs and proponents of sustainable agriculture have long been critical of the Green Revolution approach to solving problems of poverty. Through a network of International Agricultural Research Centres (IARCs) spread throughout the developing world, the narrow focus of green revolution plant breeding resulted in an emphasis on high-yielding varieties dependent on capital-intensive inputs such as chemical fertilizers and irrigation. Widespread adoption of Green Revolution varieties has fostered genetic erosion of traditional crop varieties, while encouraging non-sustainable production systems biased to larger farmers. The interests and needs of poor farmers in the Third World have been frequently marginalized in the process.

These criticisms have not fallen on deaf ears. The Rockefeller Foundation readily acknowledges the "unintended consequences" resulting from Green

Revolution technologies. A part of the Foundation's rice biotechnology program is therefore directed "at generating a more complete understanding of the consequences of technical change." The Foundation's willingness to study and incorporate the social and economic impacts of technological change in its rice program is an important step, though it does not alter the underlying premise that new technology applied to Third World agriculture offers the greatest potential for feeding poor people and overcoming land constraints.

Nevertheless, the Rockefeller Foundation's longterm commitment to rice biotechnology is impressive as a truly international collaborative project utilizing a multi-pronged stategy. Dr. M.S. Swaminathan cites Rockefeller's rice biotechnology program as an example of "a pro-poor bias in biotechnology research and application." [4]

Developing Priorities for Biotechnology Research

Green Revolution rice varieties are now grown on more than half of the rice crop area in South and Southeast Asia, though these high-response varieties are concentrated on irrigated lands. It is generally recognized that the solution to further increasing rice productivity is not a narrow-focused strategy of raising yield potential of irrigated rice. Irrigated rice lands throughout Asia are degrading (and even shrinking in some cases) because of problems of salinity, waterlogging and siltation. The human health and environmental costs of fertilizer and chemical-intensive cultivation also raise serious questions about sustainability of these methods.

The Rockefeller Foundation aims to "balance" priorities for biotechnology research among agronomic traits that would be applicable in poor production environments and traits that would contribute most to increasing rice production. In addition to raising yield potential of irrigated rice, there is also emphasis on: 1) achieving durable resistance to diseases and insects, and tolerance to abiotic stresses (such as drought and salinity);
2) increasing productivity in less favorable production environments (rainwater, upland and deepwater areas).

Rockefeller's research priorities for rice biotechnology were developed using complex analysis, taking into consideration the severity of problems/challenges facing rice production in various agroecologies, environmental factors, potential impact on poverty, the time required to solve each problem and the potential effectiveness of using biotechnology to address each problem.

Input on the priorities for rice biotechnology came primarily from biological scientists knowledgeable with each rice region; there is no mention of farmers or informal sector representatives participating in this process. The following is Rockefeller's "Rank Order of Priority Traits" for rice biotechnology:

Resistance to tungro virus
Resistance to yellow stemborer
Resistance to gall midge
Cytoplasmic male sterility
Drought tolerance
Resistance to brown planthopper
Submergence tolerance
Greater lodging resistance
Seedling vigor
Resistance to ragged stunt virus
Tolerance to waterlogging
Resistance to leaffolder
Resistance to sheath blight
Cold tolerance at seedling
Apomixis
Tolerance to coastal saline/acid sulfate conditions
Resistance to bird damage
Resistance to storage pests
Resistance to bacterial blight
Resistance to blight
Resistance to blast

Rice Genetic Maps and Markers
Developing a knowledge base and biotechnology tools has been the Rockefeller Foundation's first goal in developing the rice biotechnology program. Under the direction of Steven Tanksley at Cornell University, a genetic map of rice is being developed that will allow conventional breeders as well as genetic engineers to identify important gene components and follow their inheritance. In China, Rockefeller Foundation-supported scientists have also launched a rice genome project. In Japan, a public-private venture supports the world's largest gene mapping effort.

Identifying genes responsible for important traits and then understanding how to regulate their expression in rice is the essential knowledge base needed prior to achieving faster and more efficient genetic engineering for important agronomic traits. Ultimately, the use of genetic maps and markers will enable researchers to clone genes that are responsible for known traits. By all accounts, a genetic map of rice is transpiring faster than expected. At Cornell, researchers have assembled a "crude" map containing 400 markers, and several genes of economic importance have already been tagged with markers.

Hybrid Rice
A general goal of rice biotechnology is to increase rice yields by expanding the area planted to hybrid rice. Hybrid vigor contributes to high rice productivity on nearly 10 million hectares in China, but hybrid rice varieties suitable for tropical Asia have not yet been released. (IRRI is now pursuing this goal.) Production of hybrid rice seed in China is a labor and skill-intensive process. Hand removal of anthers for seed production is considered impractical, and therefore a genetic substitution for hand emasculation is considered essential. Rice scientists are now pursuing several routes for the development of hybrid rice, including cytoplasmic male sterility and nuclear male sterility (see description of Plant Genetic Systems' genetically-engineered male sterility gene, for example, p. 12).

Asexual reproduction through seed is known as "apomixis." A longterm goal for rice biotechnology is to exploit the potential for apomixis in the development of rice hybrids. Apomixis could greatly facilitate hybrid seed production because, once a productive hybrid is produced, it could be multiplied easily and quickly through apomictic seed production of successive generations. Apomixis could be an important development for poor rice farmers because it would enable them to benefit from hybrid vigor without having to purchase new seeds for each crop. Rockefeller Foundation scientists predict that benefits from apomixis would be 50% of the gains from hybrid seed, and could apply to all rice throughout the developing world.

Exploiting Wild Genetic Resources
Although there are 22 species of rice, only two are cultivated. Wild species of rice are found throughout the tropics, and show a remarkable range of adaptation to diverse habitats, including various biotic, soil, and climatic stresses affecting cultivated rice. Wild species of rice do not normally cross with cultivated rice, but new and improved techniques such as embryo rescue, protoplast fusion, and transformation are being used to overcome these barriers. Emphasis is now being placed on determining the utility of wild-rice genes, and isolating agronomically important genes.

Exploitation of wild rice genetic resources is not new.[5] For example, it was a wild rice from Hainan Island, China that was found to cause male sterility when crossed with cultivated rice. This discovery led to the development of hybrid rice in China. Another example comes from a wild rice variety collected near Gonda, Uttar Pradesh, India that was found to have the only gene conferring resistance to grassy stunt virus strain 1. Biotechnology offers methods that will increase the range of wild rice species that can be used in breeding programs and genetic engineering in the future.

Novel Genes for Rice Improvement

Theoretically, genetic engineering should make it possible to incorporate essentially any gene from any source into rice. Rockefeller-supported researchers are investigating, for example, the use of viral genes for resistance to rice tungro virus, and Bacillus thuringiensis (B.t.) toxin genes for resistance to yellow stemborer and other insects. Wheat genes are being targetted as possible inhibitors of rice weevil.

A team of Japanese scientists recently reported the development of transgenic rice varieties resistant to stripe virus. The breakthrough is significant because it is the first successful use of the viral-coat-protein strategy in a cereal crop. Although genes for virus resistance using the viral coat protein have been engineered and field tested in tomatoes, potatoes, cantaloupe and squash, scientists do not understand how coat protein protection really works. Questions have been raised about potential problems related to genetically engineered virus-resistant plants. More specifically, there is concern that widespread use of transgenic virus-resistant plants may exacerbate virus diseases.[6] (See *RAFI Communique,* September/October, 1992, "Emerging Technologies for Potato" for further background.)

Recent Advances in Genetic Engineering

In 1987, a team of Rockefeller-funded scientists at the University of Nottingham, U.K., was the first to report that a fertile, transgenic rice plant had been regenerated from rice protoplasts. Japanese scientists published the results of a similar breakthrough at about the same time. The development of transgenic rice plants via protoplasts was a significant breakthrough because it was the first time that scientists had succeeded in genetic engineering of a major cereal crop. Basically, the technique involves transferring DNA, the basic genetic material, from bacteria into rice protoplasts (single cells from which the cell wall has been removed). Mature plants regenerated from the protoplasts then transmit the foreign DNA to their offspring.

Despite the significance of rice genetic transformation via protoplasts, the technique was of limited value because no elite variety could be regenerated from single cells. It would take 2 to 5 years of backcrossing to genetically transform an elite variety.

In 1991 scientists at Agracetus based in Wisconsin, USA, announced the successful gene transfer of rice using a proprietary "electric discharge particle transformation." The discovery is significant because the new gene transfer technique enables scientists to introduce virtually any gene into elite rice varieties in about 8 to 10 weeks,[7] circumventing the need for the more elaborate and time-consuming gene transfer systems depending on protoplasts. Agracetus is a 11-year old agricultural biotechnology company that is a wholly-owned subsidiary of W.R.Grace Corporation.

According to Agracetus senior scientist, Paul Christou, the company realizes that it will not make money on genetically-engineered rice varieties, and has offered to provide access to the technology, at cost, to developing countries through the Rockefeller rice program and collaborating laboratories.[8] Despite Agracetus' repeated offer to provide transformation services using its proprietary gene gun to IRRI and other prestigious laboratories, Christou claims that Rockefeller grantees have consistently declined this offer "because of the scientists' ego." Because of the reluctance to accept Agracetus' offer, Christou remarks that "the technology has been shelfed" and it is "de-railing the Rockefeller Foundation's efforts."

Dr. Gary H. Toenniessen, Head of Rockefeller's Rice Biotechnology Program responds that Agracetus' offer, even at cost, is a considerable amount of money. Toenniessen explains that, scientists supported by Rockefeller are very close to developing their own rice transformation capacity that is very similar to that of Agracetus. Toenniessen adds, "We'd rather invest in developing a capacity that is freely available to all rice scientists rather than utilizing a service that is more or less a trade secret."[9]

The Rockefeller Rice Program and Intellectual Property Rights

One of the primary reasons that Rockefeller's rice program is deemed "pro-poor" is because it will seek to transfer non-proprietary rice varieties to Third World farmers without royalties. Free exchange of research materials and international collaboration are hallmarks of the Rice Program. Dr. Swaminathan explains the Rockefeller program's policy in regard to intellectual property rights on rice:

"In general, the developing world farmer should have access to varieties at the lowest possible price and should pay no royalties, or at most nominal royalties. If there is exclusivity at this level, it should be only to facilitate effective distribution.

"It is expected that Rockefeller Foundation rice biotechnology grantees will share materials and technology resulting from Foundation-supported research with cooperating researchers at zero royalty for use in developing countries. Grantees should not enter into agreements that conflict with this obligation."[10]

It is important to note, however, that Rockefeller Foundation grantees are free to pursue intellectual property rights in developed countries. According to Swaminathan, "...it is recognized that grantees may wish to pursue intellectual property rights on their discoveries and their improved materials in order to obtain economic return in developed countries for the support of further research and to maintain a stong bargaining position in the event of any intellectual property disputes."

Though clearly well-intentioned, the Foundation's "double-standard" on patenting of new rice technologies, raises important questions about the principle of Farmers' Rights, and possible conflict regarding the practical meaning of international collaboration/exchange amongst scientists. For example, Dr. Steven Tanksley of Cornell University is funded by Rockefeller to develop a map of rice genes and markers in close collaboration with IRRI (Philippines) as well as other laboratories in both the developed and developing world. Dr. Tanksley's lab at Cornell is designated by Rockefeller as the repository and distribution center for all rice probes and markers produced as part of the Foundation's program. Many international scientists were thus surprised to learn that Cornell University is now offering non-exclusive licenses for RFLP rice probes developed by Dr. Tanksley's research program. The cost of the probes begins at (US) $1,000 each.[11]

Rice Bio-Safety

In September, 1992, rice experts from around the world gathered in Cholburi, Thailand for the "International Consultation on Rice Biosafety." The meeting was sponsored by the Rockefeller Foundation, World Bank, and the United States Department of Agriculture. NGOs were not invited to participate. Participants discussed the potential biosafety and environmental consequences of large-scale plantings and commercialization of transgenic rice varieties in Asia, the genetic homeland of rice. (Published reports from the rice biosafety meeting are not yet available, but RAFI spoke to scientists who attended the meeting.)

The primary issue discussed by participants is the potential for natural gene flow between transgenic cultivars and wild relatives of rice that are found in the centre of origin. Scientists already know that gene flow occurs spontaneously in nature. The question is not whether gene flow will occur--but what genes might confer an advantage to wild relatives, and what the consequences might be in the surrounding ecosystem. If herbicide-tolerant genes, for example, were transfered from a transgenic rice variety to weeds growing nearby, the herbicide tolerant weed could become very expensive to control. Given that herbicide tolerant rice plants are likely to be one of the first "practical applications" of rice genetic engineering,"[12] this example of gene flow deserves careful consideraton.

Most scientists conclude that very little is actually known about gene flow. Given the importance of wild rice genetic resources throughout Asia, and the potential for large-scale plantings of transgenic rice varieties in the 21st century, these issues require in-depth study prior to widespread use of genetically engineered varieties. At the present time, few Southeast Asian countries have adopted regulatory programs to oversee the field testing and commercialization of transgenic crops. According to a U.S. Department of Agriculture scientist, Thailand has recently received a request from Plant Genetic Systems of Belgium to conduct field tests of transgenic maize.

Issues related to biosafety and environmental impacts of genetic engineering must not be overlooked in the rush to develop rice varieties with "superior" agronomic qualities. NGOs should play a role in the discussion and development of regulations to protect human health, safety and the environment. It is also worth noting that risk assessment of transgenic crops now being undertaken in the United States and other industrialized countries does not take into account the fact that potential impacts may be more significant in areas of plant genetic origin or centres of diversity for certain crops like rice.

NOTES

1. Rockefeller Foundation, "International Program on Rice Biotechnology: Financial Summary, Jan. 1985-Sept. 1992.
2. Rockefeller Foundation, Appendix A, International Program on Rice Biotechnology, September, 1992. "RF Grant Funds to Developing-Country Institutions for Research and Capacity Building."
3. Dr. Edward C. Cocking, School of Biological Sciences, Nottingham, U.K., funded by a $450,000 grant from Rockefeller, quoted in Biotechnology Newswatch, 6 Aug. 1990.
4. Swaminathan, M.S., 1992, Contribution of Biotechnology to Sustainable Development within the Framework of the United Nations System, United Nations Industrial Development Organization, p. 26-27.
5. See, Vaughan, D.A. and L.A. Sitch, 1991, "Gene Flow from the Jungle to Farmers," in BioScience, Vol. 41, No. 1, p. 27-28.
6. De Zoeten, G.A., 1991, "Risk Assessment: Do We Let History Repeat Itself?" Phytopathology, 81:585-586.
7. Personal communication with Dr. Paul Christou, Senior Scientist, Agracetus Co., October 28, 1992.
8. Ibid.
9. Personal communication with Dr. Gary Toenniessen, Rockefeller Foundation, November, 1992.
10. Ibid.
11. Personal communication with Walter Hoyster, Cornell University Research Foundation, Inc., November, 1992.
12. Toenniessen, Gary H., 1991, "Potentially Useful Genes for Rice Genetic Engineering," in Rice Biotechnology, CAB International, p. 272.
13. Grooms, L.W., 1991, "Agracetus Builds Position," Seed World, December, p. 21.

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This issue of the RAFI Communique was written by Hope Shand. RAFI Communique is published by the Rural Advancement Foundation International. RAFI is a non-profit, non-governmental organization that monitors the social and economic impacts of new technologies and provides information and analysis to those who are directly affected.

ADDITIONAL PUBLIC AND PRIVATE SECTOR RESEARCH ON RICE BIOTECHNOLOGY

In addition to Rockefeller-supported research, several biotechnology companies in Japan, Europe and the United States, as well as the Japanese government, are pursuing the application of new technologies to rice. The following is a brief (and incomplete) survey:

JAPAN'S NATIONAL INSTITUTE OF AGROBIOLOGICAL RESOURCES (Ministry of Agriculture, Forestry and Fisheries) also has a major commitment to mapping the rice genome, in cooperation with private Japanese corporations. Launched in 1991, the Japanese program is a 7-year, $25 million project that involves up to 100 scientists to produce a high-resolution map of the rice genome and sequence the most important genes. To receive free newsletter on rice genome project, write: Rice Genome Research Program, Natl. Institute of Agrobiological Resources, 2-1-2, Kannondai, Tsukuba, Ibaraki 305, Japan (FAX: 81-298-38-7468).

AGRACETUS, a wholly-owned subsidiary of W.R. Grace is using its patented "gene gun" to genetically transform rice plants. The device transforms cells by firing microparticles coated with DNA into them. Although Agracetus is concentrating on more profitable crops like maize, cotton and soya, the company has successfully introduced an herbicide tolerant gene into two rice varieties--the Asian variety IR-54 and the U.S. variety Gulfmont (see page 5 for further background on Agracetus). According to Agracetus Chairman, Robert Walton, "Our charge is to develop patentable processes or products. We strive for that rather than for short-term profits."[13]

PLANT GENETIC SYSTEMS N.V. (PGS), a plant biotechnology company in Ghent, Belgium has pioneered the research and development of the genetically engineered "male sterility gene" for producing hybrid rice. The company has licensed its technology to **JAPAN TOBACCO, INC** of Tokyo (a state-owned corporation), to develop a better variety of hybrid rice. In 1989, Japan Tobacco made a $6 million equity investment in PGS. Using novel genetic techniques, the companies aim to develop a cost-effecient system for developing hybrid rice by shortening the breeding cycle and eliminating the need for manual hybridization methods. The company's long-term goal is to jointly commercialize hybrid rice seed varieties.

PLANTECH RESEARCH INSTITUTE in Yakohama, Japan is a company formed by **MITSUI CORPORATION** and **MITSUBISHI CHEMICAL INDUSTRIES**. Scientists at Plantech recently announced the development of two genetically engineered rice varieties that resist infection by the rice stripe virus. The virus is transmitted by the brown planthopper insect, and destroys rice crops valued at millions of dollars each year in Japan, Korea, China, Taiwan and the former Soviet Union. Plantech's announcement is especially noteworthy because it represents the first successful use of the viral-coat-protein strategy for engineering virus resistance in a cereal crop. Plantech's genetically engineered rice plants will be field tested in 1993.

Additional Sources of Information

Rice Biotechnology Quarterly (a newsletter available from Rockefeller Foundation) write:
The Rockefeller Foundation
1133 Ave. of the Americas
New York, NY 10036

Rice Genome (newsletter available from Japanese rice genome program) write:
Editorial Office of Rice Genome
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National Institute of Agrobiological Resources
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Tsukuba
Ibaraki 305, Japan (fax: 81-298-38-7468

Rice Biotechnology, edited by G.S. Khush (IRRI) and G.H. Toenniessen (Rockefeller Foundation) published by CAB Intl. with IRRI, 1991. This book is probably available from IRRI: P.O. Box 933, 1099, Manila, Philipines.

To receive published report (forthcoming) on rice biosafety meeting held in Thailand, October 1992, write:

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News and Updates from RAFI

This issue of ***RAFI Communique*** was originally prepared as a "Backgrounder on Rice Biotechnology" for participants attending a conference on "Rice, Food Security and the Ecology," held in Chiang Mai, Thailand, 8-14 November, 1992. This highly successful meeting was hosted by the Southeast Asian Regional Institute for Community Education (SEARICE), a Southeast Asian NGO, in cooperation with three northern-based NGOs: The Dag Hammarskjold Foundation, RAFI and GRAIN. Its 63 delegates included government and NGO representatives from seven Southeast Asian states, three International Agricultural Research Centres (IARCs) active in Southeast Asia, and cooperating northern NGOs. It was the first time that governments, NGOs and representatives from the IARCs had met together in Southeast Asia and set the stage for future cooperation.

Update on Bacillus thuringiensis (B.t.) Resistance: Rice is just one of many crops that is being genetically engineered to contain insecticidal proteins from the naturally-occurring microbe, *B.t.* Past issues of the *RAFI Communique* have reported on numerous biotechnology and agrichemical corporations that are collecting strains of *B.t.* from around the world to engineer transgenic, insect-resistant crop varieties. The development of safe, biological insecticides is a welcome alternative to chemical pesticides, but scientists warn that if *B.t.* is mis-used or over-used in new varieties, insect pests will develop resistance to the insecticidal genes. Until recently, it was generally believed that as insects became resistant to one *B.t.* toxin, that toxin could be successfully replaced by a different *B.t.* toxin. As one industry spokesperson put it: "There's no need to panic. If you are getting *B.t.* resistance, you're talking about one gene and there are literally thousands of *B.t.* genes out there." (AgBiotechnology News, Jan./Feb., 1991). Unfortunately, the problem of *B.t.* resistance is not that simple.

A new laboratory study conducted on *B.t.* resistance by scientists at North Carolina State University (USA) reveals that insects can develop broad-spectrum resistance to *B.t.* toxins that differ significantly in structure and activity. According to the scientists: "Our findings indicate that selection with a single *B.t.* toxin could lead to broadly based resistance that would preclude control of an insect population with any *B.t.* product." The results of this study underscore the importance of using *B.t.* in a responsible, carefully-managed way that will not squander the use of these naturally-ocurring, insecticidal genes. Will industry listen? (Source: Gould, F. et al., "Broad-spectrum resistance to *Bacillus thuringiensis* toxins in *Heliothis virescens*," Proc. Natl. Acad. Sci. USA, Vol. 89, pp. 7986-7990, Sept. 1992.)

Update on bovine growth hormone: The October, 1990 issue of *RAFI Communique* reported on field trials and commercial sale of bovine growth hormone (BGH) in the developing world. BGH is still undergoing review in the United States, and is not commercially available. A report released earlier this year by the U.S. Congress recommended that the U.S. government withhold approval of this controversial product and that marketing of food products from animals tested with BGH be discontinued. Meanwhile, RAFI has learned that Monsanto's BGH is now approved for sale in Brazil, Bulgaria, Czechoslovakia, Jamaica, Mexico, Namibia, South Africa, former Soviet Union, and Zimbabwe. (For more information: "*Bovine Growth Hormone: FDA Approval Should be Withheld Until the Mastitis Issue Is Resolved*" is available from: U.S. General Accounting Office, P.O. Box 6015, Gaithersburg, MD 20877, USA.