RF Bd of Trustees 3/91

RF 93001

Basic and Applied Rice Biotechnology

RF 91001

GUIDELINE: Applying Biotechnology to Developing-Country Food Crops

GRANTEE: For allocation by the officers

OBJECTIVE: To support research and training at advanced laboratories participating in the Foundation's international program on rice biotechnology.

AMOUNT: $3,000,000 in addition to RF 90031

DURATION: Period ending December 31, 1992

STRATEGY: In the field of plant biotechnology, the industrialized world is rapidly acquiring a comparative advantage over the developing world. The Foundation's rice biotechnology program seeks to counter this in two ways: by enlisting advanced plant molecular biology laboratories to undertake basic and applied research relevant to the needs of developing countries, and by building the capacity of third-world scientists and research institutions to utilize the knowledge. Individual projects are funded on the condition that they address one or more of the high-priority research objectives established for the program and that the laboratories provide training for third-world scientists and facilitate technology transfer. The goal is to produce improved varieties that can solve the rice production problems judged most critical in rice-dependent countries.

DESCRIPTION: The Foundation's international program on rice biotechnology, designed as an integrated set of research, training, and capacity-building activities, was launched in 1984. This appropriation supports continuing and new research and training programs at advanced laboratories, collaborative in nearly all cases with institutes in the developing world.

In the initial years, much of the research focused on generating the knowledge base, techniques, and protocols required for genetic manipulation of rice at the cellular and molecular level. Progress has been rapid, and several workshops have been held to transfer promising technologies to participating developing-country laboratories and rice breeding programs. More recently funding has been concentrated on identifying and formulating gene constructs that, when introduced into the rice genome via genetic engineering, may instill the top priority traits in rice. A list of the advanced laboratories currently receiving support is attached.

This past October the program's Scientific Advisory Committee* met

*Benjamin Burr, Brookhaven National Laboratory; Michael Gale, Cambridge Laboratory, John Innes Institute, England; Toshio Murashige, Department of Botany and Plant Sciences, University of California-Riverside; James Peacock, CSIRO Plant Science Division, Australia; Peter Quail, USDA Plant Gene Expression Center, California; and Ralph Quatrano, Department of Biology, University of North Carolina.

with the officers for three days. They reviewed progress to date, helped establish an overall framework for support of more focused research in the future, and evaluated new and renewal research proposals within this context. The general conclusions concerning advanced laboratory components of the program can be summarized as follows.

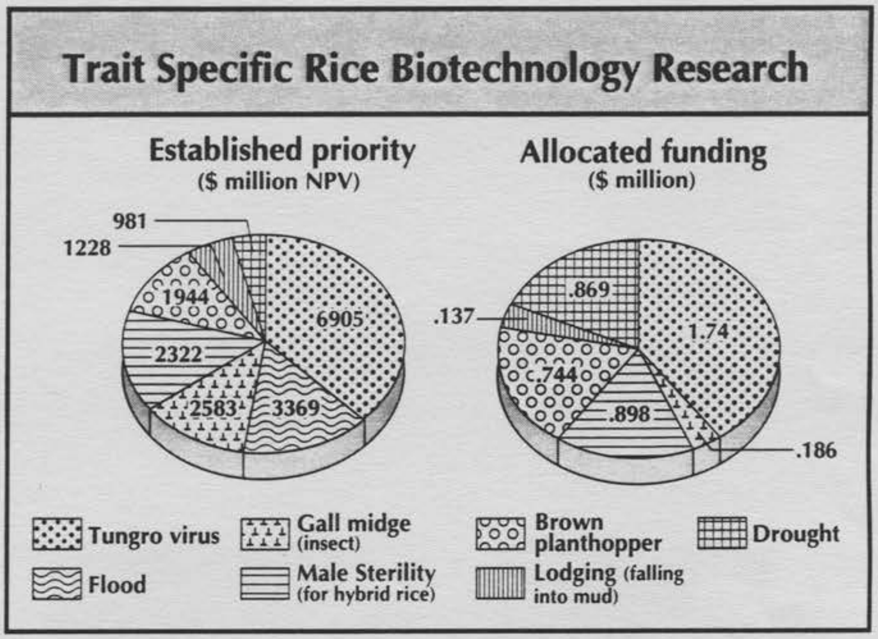
1. *Rice genetic maps and markers.* The research on development of rice genetic maps and markers and their application in rice breeding is one of the strong points of the program. The rice map now has over 500 markers, a number more than adequate to tag and follow the inheritance of important genes. Species-specific DNA markers that can facilitate the use of wild relatives of rice in breeding programs are now available. Transfer of these technologies to the International Rice Research Institute is proceeding, although at a slower pace than originally hoped. Current needs are research focused on making this technology more usable under field conditions in developing countries and improved coordination of the various gene-tagging experiments. Further development of the map as a tool for gene cloning is a longer-term goal which should be pursued.

2. *Techniques for foreign-gene transfer.* Development of techniques for the transfer of foreign genes into the rice genome was one of the early and most significant accomplishments of the program. This was a first for any cereal, and the field testing of transgenic rice plants during 1990 marked another first. But progress toward refining these techniques into routine procedures for rice genetic engineering has been disappointing. The available techniques are unreliable - sometimes they work, sometimes they do not - and when they do work, the efficiencies are low: only a few transgenic plants result and many are sterile. While this demonstrates the possibility of transformation, it will not be adequate for practical application of the technology. To develop a critical mass of effort in this area, the officers are concentrating funding on fewer laboratories.

3. *Mechanism of gene regulation in rice.* Many of the more sophisticated and powerful uses of rice genetic engineering will involve highly regulated genes that are turned on or off in particular cells, tissues, and/or organs at particular stages of plant development and/or in response to particular environmental stimuli. The relatively fundamental research aimed at understanding these control processes is proceeding well. Until recently, most of it involved repeating, in rice, investigations similar to ones conducted with model plant systems. However, the knowledge base and techniques for working with rice are now such that rice itself is becoming a model system for research on gene regulation in plants. Support for research in this area should continue at approximately the same level.

4. *Useful traits.* Most of the advanced laboratories added to the program over the past few years are concentrating on the identification and cloning of genes that can instill useful traits assigned high priority. Priorities were established by a comprehensive, quantitative analysis that incorporated estimates of the production, equity, and environmental effects

of each, as well as the likely feasibility of successfully finding and introducing a gene for each. Candidate genes for virus resistance, insect resistance, and improved nutritional quality are, or should soon be, ready for testing. Engineering complex traits - such as drought tolerance - which are controlled by many genes, will be a long-term process, but promising research strategies have been identified and are being pursued. Expansion of funding in this area will be necessary.



Established priorities are reflected in the net present value (NPV) of the increased output of rice that could be produced in developing countries if each of the identified production constraints was removed. Rice is priced at $200/ton; the time to complete research, maximum adoption area, suitability for biotechnology, equity impact, environmental effect and amount of loss prevented are each specific to a given trait.

RISKS/EVALUATION: In the field tests of genetically engineered crops that have been conducted so far, the new traits derived from "alien" genes - genes taken from other species - have almost all been effective, and the officers no longer see a risk that such alien genes will not work. However, the costs of transformation are still high and will need to be lowered for routine use of the technology in developing countries. There remains a risk that those designing and using genetically engineered plants will not give adequate attention to the principles of ecology and population biology which can enhance and prolong the usefulness of the new traits.

Evaluation will be based on the officers' assessments, assisted by the Scientific Advisory Committee, of progress by the advanced laboratories in

generating the tools for genetic manipulation of rice and identifying genes or genetic modifications that can add useful new traits to rice, and on their effectiveness in collaborating with and training researchers from developing countries as appropriate.

BUDGET: The appropriation, plus $20,000 remaining in RF 90031, would be used as follows to renew support for several laboratories currently part of the program and to support a few new research projects:

Rockefeller University	$ 600,000/3 yrs.
Texas A&M University	450,000/2 yrs.
University of Ghent	400,000/2 yrs.
Salk Institute	350,000/3 yrs.
University of Nottingham	240,000/3 yrs.
University of Georgia	200,000/3 yrs.
Swiss Technical Institute	200,000/2 yrs.
Plant Genetic Systems, Ghent	180,000/2 yrs.
Kansas State University	100,000/3 yrs.
Purdue University	100,000/3 yrs.
New projects	200,000
Total	$3,020,000

FURTHER SUPPORT: The officers expect to recommend further support for the rice biotechnology program at roughly the present level.

Developed-Country Laboratories Participating in the Foundation's International Program on Rice Biotechnology

University of California at Berkeley	Barbara Baker	Transposable elements
University of California at Davis	Bill Lucas	Genetic transformation
Commonwealth Scientific, Industrial, and Research Organization, Australia	Wayne Gerlach	Resistance to ragged stunt virus
	Merv Ludlow	Drought tolerance
Cornell University	Steve Tanksley	Genetic maps and markers
	Ray Wu	Genetic transformation/seedling vigor
University of Durham	Don Boulter	Insect resistance
University of Georgia	Gary Kochert	Genetic markers
	Sue Wessler	Transposable elements
University of Ghent	Marc Van Montagu	Gene regulation/salt tolerance
Hokkaido University	H. Uchimiya	Genetic transformation
Jacques Monod Institute	Anne-Lise Haenni	Resistance to hoja blanca virus
John Innes Institute	Roger Hull	Resistance to tungro virus
Kansas State University	Jan Leach	Bacterial-blight resistance
	Gerald Reeck	Insect resistance
	S. Muthukrishnan	Sheath blight resistance
University of Kyoto	Kunisuke Tanaka	Improved quality of rice storage protein
University of Leiden	Robert Schilperoort	Genetic transformation/gene regulation
Michigan State University	Andrew Hanson	Drought tolerance
	Mark Whalon	Insect resistance
University of Missouri	Perry Gustafson	Genetic markers
	Roy Morris	Yield enhancement
National Institute of Agronomic Research, France	David Tepfer	Drought tolerance
Northeast Missouri State University	Brent Buckner	Carotenoid synthesis in endosperm
University of Nottingham	E. C. Cocking	Protoplast techniques
Pennsylvania State University	W. Schuh	Field testing
University of Pennsylvania	Joe Ecker	Genetic mapping
University of Perpignan	Michael Delseny	Genetic markers
Plant Genetic Systems	M. Peferoen	Insect resistance
Purdue University	Thomas Hodges	Genetic transformation
	John Hamer	Blast resistance
	Ray Bressan	Drought tolerance
Rockefeller University	Nam-Hai Chua	Gene regulation/drought tolerance
Salk Institute	Chris Lamb	Defense genes
Stanford University	Virginia Walbot	Mitochondria genes/cold tolerance
Swiss Federal Institute of Technology	Ingo Potrykus	Genetic transformation system for *indica* rice
Texas Tech University	Henry Nguyen	Drought tolerance
University of Washington	Eugene Nester	*Agrobacterium*-mediated transformation of rice
Washington State University	Gyn An	Yield enhancement
	Tom Okita	Storage proteins/starch synthesis
	Hei Leung	Blast resistance
Washington University	Roger Beachy	Resistance to tungro and yellow mottle viruses
University of Wisconsin	Sally Leong	Blast resistance