

## **THE CEREALS GENOME INITIATIVE: ADVANCED GENETICS FOR THE DEVELOPING WORLD**

ASSURING SUSTAINABLE AGRICULTURAL PRODUCTION AND ALLEVIATING POVERTY THROUGH APPLICATION OF PLANT BIOTECHNOLOGY

*A Research Partnership among the United States Scientific Community, International Agricultural Research Centers, and National Agricultural Research Systems in Developing Countries*

### ***Goal***

Eliminate future critical food shortages and help alleviate poverty in developing countries, especially in Africa and South Asia, by increasing the productivity, sustainability, and profitability of cereal-based agriculture in developing countries and in the US.

### ***Objective***

Join cereals genomics researchers in the US with those in International Agricultural Research Centers (IARCs) and National Agricultural Research Systems (NARS) in developing countries in a multi-year program to apply cutting edge genetic research to the most serious constraints and promising opportunities for global and US cereals systems.

### ***The Products***

- Greatly improved understanding of the genetics of key traits across the cereals
- A highly skilled cadre of genomics researchers in developing countries capable of applying the tools of biotechnology and plant genomics to solving critical problems in agricultural development
- Tools that will be applicable across a broad array of crop species and applicable by IARCS and NARS in developing countries
- The means to improve cereals varieties that enhance agricultural productivity, improving the economic, physical, and social well-being of poor, small farmers and consumers, particularly in Africa and S. Asia

### ***The Challenge***

- Global population and economic growth will drive the demand for food - primarily cereals – to increase by 50% or more in 20 years, and conventional research will be unable on its own to meet that challenge
- Poverty and poor nutrition, especially for women and children, will continue to be serious in Sub-Saharan Africa and Central and South Asia
- Cereals constitute ~60% of caloric intake of the poor in developing countries; improving cereals productivity will have immediate and direct impact on the nutritional status of the poor
- The despair of abject poverty is a fertile breeding ground for pawns of future extremists

- Increasingly intensive cereals-based agriculture in the US and world-wide will be more vulnerable to weather extremes demanding that crops be more stress tolerant and resilient
- The impact of modern agriculture on the environment must shrink if we are to meet the demands for more and better quality food while preserving our best lands and ecosystems

### *The Science*

- The revolution in modern genomics now reaches beyond the human genome and into the realm of our most important crops – the cereals
- The genomes of the cereals are remarkably similar
  - What we learn about the genetics of one of the cereals, e.g. rice, can be applied to more complex crops like wheat and corn and to “orphan crops” like the millets that are important staples for the poorest of the poor in Sub-Saharan Africa
  - Learning how genes function in one crop will help us improve the function of similar genes in other crops
  - Transferring genes from one crop to another will help us add important traits like drought tolerance and disease resistance that are absent in some of the most important cereals
- Two rice genome sequencing projects are making the full genetic sequence of rice freely available in the public domain
- The twin revolutions in bioinformatics and broadband Internet-based communications allow analysis, storage and public access to the enormous bodies of data generated in cereals genomics research. Increasingly this information can now be accessed directly by the more advanced NARS
- The power of comparative genomics and its potential for making a major contribution to solving intractable problems in crop improvement was affirmed at the recently-concluded Intercenter Crop Genomics Meeting held at IRRI (April 1 & 2, 2002). This meeting included senior crop genomics researchers from all IARCs involved in crop improvement, as well as very senior geneticists from the US and the UK. A major conclusion of the meeting was that for the promise of comparative genomics to be realized close collaboration and coordination among ARIs, IARCS, and NARS will be essential.

### *The Opportunities*

- There is an excellent core of US cereal genomics research underway in the public sector
- USAID has a long history of support for US university research and has invested heavily in IARC programs focusing on the world’s most important food crops: wheat, maize and rice. This initiative is a logical extension of these investments and offers a means to jointly leverage their impact
- Leading US cereal genomics researchers from Advanced Research Institutes met with cereal geneticists from IARCs in April 2001 (See Appendix 1) and identified major opportunities for collaborative genomics research that would positively impact cereal production and utilization world-wide, especially in harsher environments in developing countries.
- Major constraints and opportunities for improving cereal productivity and utilization are similar in US and in developing countries

- Products of biotechnology can be used to improve “orphan” crops, such as the millets, that are so important for the poorest of the poor farmers
- Many applications of comparative genomics do not involve the development of transgenic crops. Therefore these applications will enjoy wide acceptance across the political and social landscape
- A concrete step to eliminate the agricultural biotechnology gap between the North and the South and between the public sector and the private sector in developing countries

### ***The Partners***

- US scientists from 18 states and numerous institutions of research and higher education participated in the initial planning meeting in Mexico, funded by the Rockefeller Foundation. This elite group of scientists represented the leaders in cereals genomics in the US and comprised the lead principal investigators on the major cereals genomics grants funded by NSF, DOE and USDA, with combined funding of \$80 million
- Scientist from IARCs with major cereals improvement efforts, and with support from senior management, have agreed to partner with the US cereals genomics scientists in collaborative research
- NARS scientists will link with US and IARC scientists for executing research via advanced graduate and post-graduate training in the US
- Willing major corporate investors in agricultural biotechnology for cereals improvement will be invited to participate given appropriate intellectual property agreements consistent with the public sector mandates of the IARCs and US institutions

### ***The Research Priorities***

In two days of intensive discussion and subsequent e-mail discussions the group developed the following research priorities:

- Characterizing the genetic diversity of the target cereal species and relating this to high priority traits as a prerequisite for cross species comparison and crop improvement
  - This offers a realistic means to effectively utilize the germplasm banks held in trust by a number of centers for cereals improvement
- Developing tolerance to major environmental constraints such as drought, heat, and nutrient deficiencies
- Developing broad-spectrum resistance to major diseases and insect pests
- Adding value to cereals by improving the nutritional quality, baking characteristics, and incorporating novel products such as nutraceuticals and industrial compounds
- Improving yield potential under a range of different environments
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### ***The Research Plan***

#### **Organization**

- The program will involve two five-year phases. Early in the first phase efforts will focus on the development of the foundation knowledge, expertise and tools in cereals genomics required for developing applications. Parallel to this, and depending on the level of funding, activities will be focused on those areas that are the closest to producing field-

ready technology, such as enhanced disease and insect resistance, and that are of particularly high priority, such as drought tolerance. The second phase will focus on further developing a wider range of applications and establishing applied genomics capacities within NARS.

- Research will be organized in a modular format (see Figure), with Trait Modules drawing on data generated by a Genetic Diversity Platform Module and other Trait Modules. Financial support for Trait Modules may be in the form of consortia grants. The modular approach will facilitate multi-donor support for the cereal genomics initiative.
- Each Trait Module will address a high-priority research target (e.g. drought tolerance), as identified in the workshop held in Mexico and subsequent discussions
  - A scientific advisory panel will develop a broad research strategy for each module. These individuals will be recognized experts in the field with a demonstrated interest in addressing problems relevant to developing countries.
  - Specific research targets within each module will be addressed as distinct projects. These projects should be awarded on a competitive basis and constitute the primary funding units of the comparative cereals genomics program. Depending on the level of funding we may seek assistance from US granting agencies in managing the granting process to assure its integrity.
  - Typically a research project will involve 3 (or occasionally more) partners: 1-2 US labs, 1-2 IARCs, and 1 or more NARS with the IARCs typically coordinating the NARS participation. Some US institutions may also have projects or activities directly with NARS.
    - Training of NARS scientists in US and IARC labs will be a major component of all modules
  - Each project will have sufficient bioinformatics input to assure that high quality data are available to all participants in a timely manner

### **Initial Implementation**

- The Genetic Diversity Platform Module will be the first to launch the initiative in association with one Trait Module. The Platform Module will undertake characterization of cereal germplasm bank collections and core breeding material. This will include the building of the basic bioinformatics and database platforms to support the overall initiative
  - Target species for characterization will be: rice, maize, wheat, barley, sorghum, and millets
  - Genetic diversity of up to 10,000 germplasm bank accessions and elite lines initially will be characterized using ~100 mapped simple sequence repeat (SSRs) markers and/or single nucleotide polymorphisms (SNPs) per line
    - These SSRs must be created and mapped for some lesser-studied species

- Using the information from the initial screening of the germplasm, subsets of each species will be analyzed using 500+ markers to provide higher genome resolution required for associative genetic mapping
- This module will also explore the possibility of using single nucleotide polymorphisms as markers for high throughput analyses
- Standardized microarray protocols will be established
- A common cereals database will be developed with: a structure that will permit searches across all species; capacity to hold the genetic diversity data for all species; sufficient adaptability to incorporate field characterization data etc. as other research modules generate them
- Data bases will be designed for remote access, convenient and secure downloading, and compatibility with other genomics data bases developed and maintained in the public sector. Quality assurance and access requirements will be similar to those imposed by other public databases and required by national funding agencies (e.g.NSF).
- Bioinformatics platforms will be developed to allow the analysis of the molecular and phenotypic data. Associative genetic approaches especially will be explored to provide potentially linked genome segments with traits of interest. The use of mapped SSRs or other markers will allow for associative genetics to be performed on an across-species (or comparative) basis.
- The first Trait Module to be addressed will most likely focus on improving drought tolerance through the application of comparative genomics. It is expected to begin concurrently with the Genetic Diversity Platform Module and build on the recommendations that emerged from the drought workshop in 1999 and the cereals genomics meeting in 2001, both sponsored by the Rockefeller Foundation and held at CIMMYT, Mexico.

The development of the drought trait module will follow the steps outlined in the Organization section. The first action will be to appoint a small (3-5 person) scientific advisory panel to develop the overall research strategy and approaches. Based on this strategy the coordinator will issue calls for proposals to formulate and execute multi-year projects. It is expected that the projects will aim to establish strong linkages between US universities and those CGIAR centers with research capacity and focus on improving the performance of cereals under drought conditions (e.g. CIMMYT, ICARDA, ICRISAT, IRRI). The supported projects will include explicit mechanisms for building upon and contributing to the information and resources generated by the Genetic Diversity Platform Module.

- Additional Trait Modules will be developed following a similar process as funding levels permit.

### **Reporting and communications**

- Funding should support an annual meeting of all senior scientist participants to monitor research progress and identify any mid-course adjustments that may be needed.
- An annual progress and financial report will be produced.

### ***Governance and Management***

- The overall cereals genomics initiative will be coordinated through a US university or an IARC. The coordinator will provide administrative support, facilitate annual meetings and coordinate financial/research reporting and external reviews. At the highest funding levels a full-time coordinator with appropriate support staff will be required. The appointment of the coordinator will be made by a selection committee composed of leading US and IARC scientists plus representatives from participating donor agencies.
- A Scientific Advisory Committee will provide scientific oversight for the entire initiative and initially help set research parameters for the Genetic Diversity Platform and Trait Modules. It will be composed of internationally respected scientific leaders in genomics research who are external to the initiative.
- A Research Management Team will provide overall monitoring and guidance for the program. It will be composed of one principal investigator from each module and be chaired by the Program Coordinator.

### ***Intellectual Property***

All intellectual property generated by the Program must be freely available for use in developing countries. Agreements to that effect will be developed and must be signed by participating institutions as a prerequisite to receiving any funds. These agreements will be modeled after those developed by other entities (e.g. the Donald Danforth Center and the National Institutes of Health) for the same purpose.

### ***Role Within the Global Challenge Program on Genetic Resources***

CIMMYT, IRRI and IPGRI are developing a Challenge Program (CP) on genetic resources for the Future Harvest (CGIAR) Centers. This CP was inspired by the Cereals Genome Initiative and will link institutions and scientists from the North and South in much the same way as we propose here. The Cereals Genome Initiative can represent a major component of USAID's investment in the CP on genetic resources. It clearly fulfills the CP rationale of attracting new partners from Advanced Research Institutions and focusing their expertise on problems relevant to developing countries and in partnership with IARCs and NARS. The modular design of this program will readily adapt to inclusion into the CP as well as to participation by other donor agencies and ARIs from different countries.

### ***External Review***

Ideally, an independent panel of respected scientists from US institutions, IARCS and NARS, will conduct midway into the third year an external scientific review of the CGI. The review will cover quality of science, quantity of output, adequacy of information exchange and communication and management and governance. An important mandate of the review team will be to advise on continued funding. However, should the Cereals Genome Initiative be incorporated into the CP on genetic resources, its review process should be incorporated into that designed for the overall CP.

### ***Financial Requirements***

- Source of support: USAID funds in the Foreign Operations Bill specifically authorizing support to plant biotechnology in developing countries.
- Genetic Diversity Platform Module (\$3 million per year for two years)
  - Characterization will require \$2 million per year for two years
  - Development of bioinformatics capacity at \$1 million per year for two years
- Four Trait Modules (\$3 – 5 million each per year for 4 – 5 years)
  - 3 – 5 research projects per module
    - Each module will have a bioinformatics component
  - Each project will have 3 – 5 participating institutions/labs
    - ~ \$100 – 250 K per lab per year
- Governance and Management (at the high end of funding)
  - Administrative support including supplies and travel (\$350K per year)
  - Annual conference (\$100K per year)

### **Financial Breakdown by Year**

- Year 1: \$3 – 5 million
- Year 2: \$8 – 12 million
- Year 3: \$15 million
- Year 4: \$15 million
- Year 5: \$15 million
- Total for 5 Years: \$56-62 million

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## Appendix 1

### *List of the participants*

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