Advancing Cutting-Edge Science to Boost Rice Production, Increase Farmers’ Incomes, and Conserve the Environment

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What is rice?

Perhaps the oldest domesticated crop

• Tremendously diverse

More than just food

• Though it is the primary staple for billions (~ 50% of world & ~ 75% of poor)

Flourishes in an exceedingly wet monsoon environment

• Impossible for other staples
Rice is typically grown by small family farm enterprises (<2 ha)... saved seed

Animal draft power

Reliance on human labor...

For how long?
If we want to do something about poverty, it is clear that we must invest in rice.

Rice Consumption
Annual consumption per capita

Poverty
Each dot represents 250,000 people living on less than $1.25 a day, 2005

90% of the world’s rice is produced and consumed in Asia over 70% of the world’s poor are in Asia, but African rice consumption growing rapidly.
Mission:

Reduce poverty and hunger,

Improve the health of rice farmers and consumers,

Ensure environmental sustainability

Through research, partnerships

Home of the Green Revolution
Established 1960

A case study in applying research to development
The Green Revolution in Asia

1960s
- yields ~1.5 t per ha
- widespread famines predicted

Today
- yields ~4 t per ha
- economic growth

IR8 (semi-dwarf) launched the Green Revolution and saved millions from starvation

Science doing what people said could never be done

Annual rate of yield increase:
52.4 kg grain/ha
\( (R^2=0.982) \)
ACIAR 2011 impact assessment of IRRI’s rice breeding Vietnam, Indonesia, Philippines

$1.46 billion per year from 1985 - 2009

“This means farmers are now harvesting more rice per hectare, which not only lifts them out of poverty, but contributes toward the worldwide challenge of feeding the estimated global population of 9 billion people in 2050,” Minister for Foreign Affairs Kevin Rudd September 2011.
Yield growth stagnating after complacency

Pardey et al. directly relate decline in public sector investments to productivity growth decline
Monthly export price (US$/ton FOB) of Thai rice (5%-broken), March 1998 to July 2011

Total Number of Hungry People, 2001-2010

Source: United Nations Food and Agriculture Organization (FAO)

Source of raw price data: The Pinksheet, World Bank
Global per capita rice consumption has remained stable for last ~ 25 yrs
Global rice production increases needed to meet demand by 2035

Additional rice needed: 114 million tons by 2035

2010 global rice production

Asia  ▢  Africa  ▪  Americas  □  Rest of world
Where Will the World’s Rice Come From?

Ideally from increasing productivity on existing rice lands, mostly in Asia, (in 20+ years increasingly from Africa)

BUT, in Asia:

Land is moving out of rice
Labor is moving out of rice
Water is moving out of rice

Major changes in production practices and increases in efficiency *Just to stay where we are*

If Asia does not produce sufficient rice, the world will be food insecure
To Meet Tomorrow's Food Needs and Address Challenges of Nutrition and Poverty Under a Changing Climate

A Second Science – Based Green Revolution is Needed
CGIAR Research Program (CRP) 3.3.

An evolving alliance of IRRI, AfricaRice & CIAT with Cirad, IRD, JIRCAS and ~900 research and development partners worldwide.

Each dot represents 5,000 ha of rice.
GRiSP Approach

15-20%  25-30%  20-30%  5-10%  5-10%  10%

1 Genetic Resources
2 New Varieties
3 Production Systems
4 New Products & Value Chains
5 Targeting & Policy
6 Regional Delivery

Global and Regional R&D Product Lines
- 2.1. Informatics and MET
- 2.2. Improved traits
- 2.3. Stress-tol. rice
- 2.4. HY irrigated rice
- 2.5. Hybrid rice
- 2.6. Healthier rice

Activities - Product demand
Milestones - Product demand

Partners

Outcomes (Regional)
Impact

- 5-yr work and business plan: 2011-2015
- Interdisciplinary, product-oriented R&D: 94 R&D Products clustered in 26 Product lines under 6 Themes
- New frontiers research
- Science capacity building
Ex-ante assessment, priority setting, information & targeting (T5)

- Product development (T1-T5)
- Product adaptation and dissemination (T6)

Ex-post impact assessment (T5)

R | D
---|---
Development partners
Direct research partners

Direct research partners

Development partners
Science – based?

- Tap the revolutions in genetics, molecular biology and plant physiology
- Link soils biology and chemistry to better understand and manipulate sustainable nutrient supply
- Exploit the explosion of computation capacity and remote sensing to model systems and link process at scales from the cellular through ecosystems and regions
- Proactively link the political and social dimensions of agriculture to technology development
Cannot Overestimate Central Role of Genetic Resources for Coming Generations

IRRI holds in trust the world’s largest collection of rice varieties...> 110,000 accessions

Less than 5% has been used in breeding programs
GRiSP Product Line 1.2. Characterizing genetic diversity and creating novel gene pools

- Durable disease-pest resistance
- Abiotic stress tolerance
- Dissemination

Future challenges

Current problems

Use

Gene Function

Conserved Germplasm
Breeding Lines
Specialized Genetic Stocks

Genetic Resources and Diversity as Foundation

Phenotype-genotype association

Conservation
Sequence and Evaluate ~10,000 Rice Accessions

• Developing high-density genotyping Affy arrays with 1 M SNPs

• Includes newly discovered SNPs from >150 genomes and from other projects

• Initial genotype 3000 rice lines spanning range of diversity

• http://www.ricesnp.org

• Partners include Cornell, USDA, AfricaRice, CIRAD, Bayer CropSciences, Syngenta, CIAT, BGI – CAAS, USAID Linkage

• Coordinated collaboration in bioinformatics & data management: adhere to highest standards of public access
Phenotype sequenced lines to support breeding: A global effort

Network
Phenotyping common genetic materials
• Core collection (2,000)*
• Special collections and genetic stocks based on desired criteria

Gene discovery provides gene function network, gene markers, promising donor lines

Breeding demand for phenotyping techniques

Breeding Programs using unique populations unique to breeding objectives

* Core collection divided into 5-6 structured populations for phenotyping

Improved methodologies

Collaboration brings together molecular biology, stress physiology, field agronomy
Near and long-term benefits

- Structure gene bank resources to improve germplasm utilization
- New genes discovery through large-scale genotype-phenotype association
- Shortening breeding cycles
  - Selection of parents for breeding
  - Targeted phenotyping
- Rapid varietal conversion with marker-added selection
- Capacity to deploy rice diversity to deal with unanticipated problems
Climate and Rice

- Global climate change will affect rice farmers for decades to come.
  - Rising temperatures can negatively affect yield. (+1 °C = 10% yield drop!)
  - Extreme environmental events can increase frequency of drought, flooding, and sea water intrusion.

- Changing rice production systems will change GHG emissions from rice fields.

The occurrence, distribution and severity of rice pests will almost certainly change with climate change.
Making rice climate-ready

- drought
- salinity
- submergence
- heat
Breeding for submergence tolerance

- Large areas of rainfed lowland rice have short-term submergence (eastern India to SE Asia); > 10 m ha
- Even favorable areas have short-term flooding problems in some years
- Flood tolerance identified in a traditional Indian variety FR 13A in 1978
  - Poor agronomic and grain quality
New *Sub1* lines after 17 days submergence in the field at IRRI
Sub1 varieties: help poor farmers to cope with perennial flooding

Eastern Uttar Pradesh

Major support from Japan USAID, B&MGF enables us to reach > 1,200,000 farmers
In 2011...millions over the next few years

Released in Bangladesh, India and Philippines 2009...
Nepal in February 2011
## Partnerships for seed multiplication & dissemination

<table>
<thead>
<tr>
<th>Partner's Category</th>
<th>India</th>
<th>B'desh</th>
<th>Nepal</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research Institutions</td>
<td>15</td>
<td>3</td>
<td>3</td>
<td>21</td>
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<tr>
<td>Universities</td>
<td>18</td>
<td>4</td>
<td>1</td>
<td>23</td>
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<tr>
<td>Government Organizations/programs</td>
<td>16</td>
<td>6</td>
<td>2</td>
<td>24</td>
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<tr>
<td>Private Seed Companies/Seed Growers</td>
<td>41</td>
<td>201</td>
<td>8</td>
<td>250</td>
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<tr>
<td>Public Sector Seed Corporations</td>
<td>8</td>
<td>1</td>
<td>1</td>
<td>9</td>
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<tr>
<td>NGOs</td>
<td>15</td>
<td>39</td>
<td>3</td>
<td>57</td>
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<tr>
<td>Farmers’ Organizations/Progressive Farmers (Seed producers)</td>
<td>15</td>
<td>11</td>
<td>1</td>
<td>27</td>
</tr>
<tr>
<td>International Organizations</td>
<td>3</td>
<td>3</td>
<td></td>
<td>6</td>
</tr>
</tbody>
</table>

**TOTAL**                                         | **131** | **267** | **19** | **417** |
400% increase in rice area is Eastern India after introduction of IR72046 salinity tolerant rice variety during Rabi/Summer Season.
Drought tolerant varieties

- Six drought tolerant varieties released during 2009-11
- Yield advantage of 0.8-1.2 t/ha under moderate to severe drought, but with no penalty under non-stress conditions

Sahbhagi dhan in India

Tarharra 1 in Nepal

Sahod Ulan 1 in Philippines
2 in 1: Drought + submergence tolerance

- QTL  + QTL  - QTL

- Three drought yield QTLs pyramided in Swarna sub1
- BC$_4$F$_2$ population with three QTLs under genotyping at IRRI
- Anjali, Savitri, TDK 1, Saro 5, Supa, NSICRc 222, MR219, MRQ74 improvement underway
In theory C4 rice could:

- increase rice yield by 50%
- double water-use efficiency
- improve nitrogen-use efficiency

C4 photosynthesis is one of the few known evolutionary mechanisms that could deliver these superior combination of benefits.
Engineering a C4 rice

Transforming Photosynthesis in Rice: Compressing a Million Years of Evolution to Twenty
It will likely take a minimum of 15 years of coordinated research carried out in the laboratories of the C4 Rice Consortium to deliver C4 rice to plant breeders in the developing world.

**Phase 1**
- Gene discovery and molecular toolbox development
- Characterize regulatory controls

**Phase 2**
- Transform rice to express Kranz anatomy and the C₄ metabolic enzymes

**Phase 3**
- Optimize C₄ function in transgenic rice

**Phase 4**
- Breed C₄ transgenics into local varieties

Engineered *all* enzymes required for C₄ into rice
Clinical and Subclinical Vit A Deficiency

Effects:
- Child mortality
- Measles suscept.
- Night blindness
- Corneal scarring
- Blindness

Approx. 400M suffer VAD globally, ~33%
SE Asia 100 - 140 million children suffer
from VAD

Micronutrient Initiative 2004
Combating vitamin A deficiency among the poor: Golden Rice

2000                      GR1 – 2004                      GR2 - 2005

1.2 – 1.8                      up to 8.0                      up to 36.7
Provitamin A Carotenoid levels (ug/g)

Work on Golden Rice began in late 1980s... to consumers in 2014
What do we do about managing our rice crop more efficiently?

Examples of nutrient and water management
Rice and Water

40% of fresh water used in Asia goes to rice production

Puddling soil and transplanting seedlings controls weeds, improves nutrient supply & holds water later in season

As labor and water use change, what does this mean for rice production?
Expected increasing water scarcity

2025: 15-20 million ha irrigated rice will suffer some water scarcity

Asia WS irrigated rice

Comprehensive Assessment
Water Management in Agriculture 2007

IRRI Data base (GIS laboratory)
## Water saving options for rice

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>Safe AWD</th>
<th>Dry seeded</th>
<th>Aerobic rice</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Land prep</strong></td>
<td>Puddled</td>
<td>Puddled</td>
<td>Not puddled</td>
<td>Not puddled</td>
</tr>
<tr>
<td><strong>Establishment</strong></td>
<td>Transplant; wet seed</td>
<td>Transplant; wet seed</td>
<td>Dry seed</td>
<td>Dry seed</td>
</tr>
<tr>
<td><strong>Water</strong></td>
<td>Flooded; saturated</td>
<td>Saturated; mild drying</td>
<td>Early: drained; then saturated</td>
<td>Drained</td>
</tr>
<tr>
<td><strong>Soil aeration</strong></td>
<td>Anaerobic</td>
<td>Anaerobic; mild drying</td>
<td>Aerobic; then anaerobic</td>
<td>Aerobic</td>
</tr>
</tbody>
</table>

Conventional | Safe AWD | Dry seeded | Aerobic rice
---|---|---|---
![Conventional](image1.jpg) | ![Safe AWD](image2.jpg) | ![Dry seeded](image3.jpg) | ![Aerobic rice](image4.jpg)
“Safe” Alternate Wetting and Drying

Irrigate when water is 15-20 cm below the surface

Keep 5-cm flooded at flowering

Main idea to convey to farmers:

• Water is there even when you can’t see it
• Create confidence by demonstration
• Farmers then to experiment with threshold value
• Independent of soil type, hydrology, variety...
AWD results

Reduce water use by ~30%

Maintain yields

With adequate weed and fertility management yields may increase up to 30%

Reduces methane (greenhouse gas) emissions from rice fields

Depends on timely and reliable water control
15 years of research provides the science for ‘precise’ field-specific nutrient management

Science is well documented

Tools are available for farmers

Partnerships after 10 years (1996-2005)

Farmers need quick and easy access to customized, science-based recommendations
“Nutrient Manager” using interactive voice response (IVR): Precision farming on < 1 ha

1. Call toll-free phone number with voice recording
2. Select a local language
3. Answer 10 to 12 questions with keypad to obtain farm profile
4. Complete in about 8 minutes
5. Transmit answers to model on high-end (cloud based) server
6. Generate advice specific to farmer situation
7. Deliver customized advice as SMS message
Nutrient Manager for Rice Philippines Version 2.1

Farmer calls 2378 using Globe SIM

Interactive Voice Response implementation box

Web output

Smartphone output

Converting to HTML 5

Web GSM mobile

SMS output

Growth stage | Days** | Harvestable yield**/ha | Earliness** | Height at 14-16 | Ear | Flowering | Fruiting | Running | Harvest
---|---|---|---|---|---|---|---|---|---
Grain filling | 52-60 | 1,490-1,640 | 14-16 | 1,548 | 10-16 | 1,968 | 2,128 | 2,128 | 1,968
Anthesis | 52-60 | 1,490-1,640 | 14-16 | 1,548 | 10-16 | 1,968 | 2,128 | 2,128 | 1,968

**/ha

Web output

Converting to HTML 5

SMS output

Interactive Voice Response implementation box

GSM mobile

Farmer calls 2378 using Globe SIM

Web output

Smartphone output

Converting to HTML 5

SMS output

Interactive Voice Response implementation box

Farmer calls 2378 using Globe SIM
Nutrient Manager released or under development and field evaluation before release

- NM Rice-wheat NW India
- NM Maize Bangladesh
- NM Rice Bangladesh
- NM Rice N Vietnam
- NM Rice Guangdong
- NM Rice Tanil Nadu
- NM Rice Sri Lanka
- NM Rice S Vietnam
- NM Rice West Africa
- NM + txt Philippines
- NM + txt Indonesia

Released in 2010

Coming in 2011
Connect farmers with relevant agricultural science and services

Suite of compelling services and financial products

Interactive Apps --- providing management guidelines

Product development and testing

- Insurance
- Input providers
- Service providers
- Microfinance
- Marketing

1. Invest wisely at start of season
   - Nutrient Manager and Rice Crop Manager

2. Protect investment during season
   - Rice Crop Doctor

Research
Consolidation of knowledge
Testing with farmers
Validation
• To develop a set of *global standards for best practices* of sustainable rice production (global rice GAP)
• To develop quantifiable *sustainability targets*
• To develop and promote decision-support tools (such as Field or footprint Calculators)
• To promote the adoption of best practices and sustainability criteria
For sound medium and long term planning, what do we need to know?

Location specific, timely and accurate information on rice production, supplies, and trends

In particular:

- What is the harvested area?
- When will it be harvested?
- What is the yield?

A combination of remote sensing and crop yield modeling can provide this information under certain conditions
Radar-based real time crop monitoring system for rice

Color shows crop establishment:
- **cyan** late Dec to early Jan
- **blue** mid-Jan
- **red & green** still under land preparation in mid-Jan

- planting dates
- rice area estimates
- crop status & yield estimates
- crop damage estimates
- crop insurance

Sentinel 1A & B satellites
Global coverage every 6 days 20-m resolution
Free
National/Global Rice Information Gateways

Policy makers

Medium-term projections
Analysis of policy impacts

Rice supply-demand-trade model

Crop growth models
Monitoring and short-term forecasting
Statistics, GIS
Remote sensing
GRiSP is Faced With...

Surge of new technologies and potential technologies to benefit changing rice community

The way rice will be grown and marketed...

Surge in the demand for these technologies

Public sector that is demonstrably unable to deliver to the end user

Transformational interest of private sector in the rice sector

Will new CGIAR provide funding at levels needed for strategic research
Excite the minds of young scientists

Rice Research to Production course
Thank you

“Since the way to feed the world is not to bring more land under cultivation, but to increase yields, science is crucial.”

*The Economist*

19 April 2008

*Rice Science for a Better World*
Help us fill the world’s rice bowls

Come join us!

http://irri.org/JoinUs
Traits being placed in commercial hybrids:
Restorer lines, Sub1, BLB resistance, BPH resistance, blast resistance to name a few
...then and now

US$ million

- **Restricted**
- **Unrestricted**

Absolute Funding Gap

- **Strategic Funding Gap**

- **CRPs W1-3**
- **Other SRF, Other income**

Inflation adjusted IRRI funding (GDP deflator, 2005=100)

- 100%
- 70-80%
- 50-70%
- 30-40%