The Wheat ‘Green Revolution’
What was accomplished?

Reversal of food shortages in India and Pakistan in 1960’s

Averted mass starvation due to exponential population growth in Indian subcontinent

National security through reduced hunger

Higher farmer income stimulated rural non-farm economies.

Better nutrition through increased income and reduced food prices

Figure: Indian Wheat Production, 1950-2000
Average wheat grain yields in the Indian subcontinent were approximately **doubled** between 1955 and 1970

*Pakistan became self-sufficient by 1968; India by 1974*

**Increased global food production**

**World grain production**

1950: 692 million tons of grain  
1992: 1.9 billion tons of grain

*Total cereal production, wheat and rice, in Asia doubled between 1970 and 1995*

*By 1990, 70% of wheat and rice production areas of developing countries were planted to modern high-yielding varieties*
Who was involved?

Ford and Rockefeller Foundations

*These Foundations initiated the 1943 Mexican Agricultural Program (MAP), which evolved into CIMMYT*

CIMMYT - International Wheat and Maize Improvement Center

US-Agency for International Development
(US AID)

Dr. Norman Borlaug –

*1970 Nobel Peace Prize winner for contributions to the Green Revolution*

*Credited with saving millions of people from starvation*
How was it accomplished?

Semidwarf genes (Rht1 and Rht2)

Identified by Salmon (USDA Ag attaché) in post-war Japan agricultural trials (1945-46), provided to WSU (Orville Vogel, 1948), from Vogel to Borlaug at CIMMYT (as F2 seed of Norin 10 x Brevor cross in 1954)

*Genes for short, stiff straw types that could withstand higher production inputs and increase grain yields*

N fertilization and management

Irrigation (intensive management)

**Result:**

*Exploit interaction of G x N x M to establish and achieve more intensive high-yield cropping systems*
Why was the ‘new’ plant type important??

Traditional varieties and land races were well adapted to local conditions, but low yielding, tall, and lodged easily, especially when irrigated or fertilized with N.

Why were record yields were obtained with the semidwarf genes, Rht1 and Rht2 ??

‘More than just changing plant height’

- Shorter stature, less prone to lodging
- Maximize light capture, more erect foliage
- Maximize partitioning of photosynthate to grain
  - Increased harvest index
- Higher and more synchronous tillering
- More responsive to nitrogen
- Shorter maturity cycle (allows for double cropping in rice)
- Increased head size and fertility
What were unique breeding contributions of CIMMYT and Borlaug?

**Shuttle breeding for spring wheat development**
- Toluca – Obregon breeding sites
  - (highly contrasting environments)
- Select for ‘daylength insensitivity’ in varieties

Result in broad adaptation, yield stability, high levels of disease resistance

**Rust and disease resistance**
- Screening and evaluation
- Discovery of new genes and their deployment
- Anticipation of changes in rust races
Major cooperators:

Swaminathan:  
Prominent Indian scientist and plant breeder, Indian Agricultural Research Institute, New Delhi. Collaborated with Borlaug on seed introductions, testing, and adoption of high yield varieties and production systems in India. Swaminathan was winner of 1987 World Food Prize for his contributions to the Green Revolution and Indian food production.

Swaminathan’s contributions in-country resulted in more rapid acceptance of semidwarf varieties and technology:

1964: introduction of 20 tons ea of varieties  
Sonora 63 and Sonora 64

1973: 10 million hectares in CIMMYT HYV’s
The Asian Rice ‘Green Revolution’ of the 1970’s

High yield, input responsive, semidwarf rice varieties developed and released by IRRI, the International Rice Research Institute based in the Phillipines.

Variety development efforts were led by Gurdev Kush, IRRI rice breeder

**IR8** - The first of the modern, high-yielding, semi-dwarf released to stave off the mass famine that was predicted for Asia in the 1970s. It out-produced all existing rice varieties by a factor of two.

**IR36** - This early maturing variety had multiple pest resistance, and had been planted to more than 11 million hectares by the 1980s.

**IR64** – Released by IRRI in 1985. IR64 had excellent grain quality, pest resistance and high yields which made it the most widely planted variety of rice in the 1990s.
Social Implications of the ‘Green Revolution’?

- Increased farmer income through increased grain yields
- Increased need for farm inputs, marketing, and milling
- General increase in demand for goods and services at rural level
- Per capita incomes almost doubled in Asia between 1970 and 1995
- Absolute number of ‘poor’ fell from 1.15 billion to 825 million in 1995
- Better nutrition at local levels through raising income, reduced prices, and enabling consumption of a more diversified diet
Why criticisms of the Green Revolution?

Environmental concerns related to intensive production practices

- Increased fertilizer and pesticide use
- Irrigation requirements, high water use, soil erosion

Some outcomes were inevitable as millions of illiterate farmers used new technologies for the first time

Also related to:
- inadequate extension programs,
- lack of regulation of water quality,
- government policies that subsidized input prices
But - What would have been the environmental impact when the alternative was to expand farming into huge areas of marginal lands and forested areas??

Total increase in cultivated land for cereals was only 4% during the Green Revolution.

**Decreased biodiversity**, increased genetic vulnerability related to monoculture, high yield varieties

**Farmers abandoned local land races to grow modern high yield varieties**

*Result: increased efforts worldwide to collect and preserve germplasm; conscious efforts to broaden genetic base of modern cultivars.*
Inequitable sharing of benefits and income among regions and within the population

Large farmers were primary adapters of technology

Encouraged unnecessary mechanization, which reduced employment

**Fact:** small farmers and landless laborers gained proportionally more income than larger farmers. Large numbers of poor people were lifted out of poverty through lower food prices, increased employment.

*Was there any viable alternative?*
Post Green Revolution Crop Improvement Strategies

Development programs now have a better understanding the conditions under which the Green Revolution and similar yield-enhancing technologies are likely to have more **equitable benefits** among farmers.

These conditions include:

1. A **scale neutral technology** package that can be profitably adopted on farms of all sizes

2. An **equitable distribution of land** with secure ownership or tenancy rights
3. **Efficient input, credit, and product markets** so that farms of all sizes have access to modern farm inputs and information and are able to receive similar prices for their products

4. **Policies that do not discriminate** against small farms and landless laborers (for instance, no subsidies on mechanization and no scale biases agricultural research and extension).

**These conditions are not easy to meet!!**

*Typically, governments must make a concerted effort to ensure that small farmers have fair access to land, knowledge, and modern inputs.*
Established in 1971 to coordinate goals and activities of 16 International Agricultural Research Centers (IARC’s). The Centers are continuing the breeding, systems research, and agricultural development work established in during the Green Revolution.

Biotechnology and the CGIAR. 2000, [www.cgiar.org](http://www.cgiar.org)
Cosponsors:

FAO – Food and Agriculture Organization of the United Nations
UNDP – United Nations Development Program
UNEP – United Nations Environment Program
World Bank

CGIAR is a publically funded network

Financed by taxpayers and philanthropic institutions.

US-AID is major contributor.

In 2002, CGIAR budget totaled $347 million.

Chairperson is VP of World Bank.
Goal of CGIAR system:

Increasing **food supply for people in developing countries** through technological improvements.

Improving **ecological, economic, and social factors**, with emphasis on poverty reduction and environmental sustainability.

The CGIAR undertakes **research** -

*that private sector is unlikely to undertake, national research programs are unable to undertake, and where international coordination is needed and beneficial.*
Examples of activities:

**Genetic improvements and variety development** - Noted for high yield varieties of wheat, maize, rice and other food crops; includes breeding of millet, sorghum, barley, root and tuber crops, legumes, etc.

**Conservation of natural resources, sustainable management practices** and IPM strategies

**Saving biodiversity** through CGIAR genebank network

**Policy research** and impact of government and international programs

Strengthening of **National Ag Research (NAR’s)** programs

**Training** of researchers, educators, extension agents, government administrators. Over 50,000 since 1971.

Applications and implications of **biotechnology for developing countries**
Application of CGIAR research:

Products of CGIAR research constitute ‘international public goods’, freely available to benefit the global public. Results are made available in the public domain.

Germplasm and varieties developed through the CGIAR system are in ‘public domain’, under auspices of FAO.

Challenge now is applications of modern biotechnology and concern that, through IPR restrictions, benefits of modern biotechnology will bypass poor people, resulting in ‘scientific apartheid’.

Centers are struggling now to deal with international IPR issues, as well as public acceptance of biotechnology in developing countries. Centers may need to take out ‘defensive IPR protection’ to maintain ‘freedom to operate’, but IPR claims also consume time and funds.
Current focus of Norman Borlaug: Sub-Saharan Africa

Lead for Sasakawa-Global 2000 agricultural program

**Collaboration with Jimmy Carter and the late Ryoichi Sasakawa of Japan.**

Focus on small-scale farmers in 14 African countries.

Concern was that ‘**Green Revolution**’ technologies and information were not reaching small farmers, or being adapted to subsistence farming, which are critical for expanding food production in Africa.

The bulk of the work of SG 2000 projects is carried out by national extension workers; this ensures that the benefits of the project will last after the project has officially ended.
Current crisis in CGIAR and AID funding:

Causes:
- Donor fatigue
- Fallout from decline in economies of Asia (1990’s) and world
- Increased competition for world aid funding (health vs food)
- International conflicts and national security priorities
- Redirection of support, research priorities (i.e., biotechnology)
- Redirection of support directly to NAR’s
  (CGIAR mission accomplished??)

Result:
- Significant decline in staffing, all CG centers
- Reduced operating and program scope (ex: CIMMYT)
- Increasing pressure to license and patent products to obtain $ support
- Increased vulnerability of developing countries
- Increased dependence on NAR’s

What might turn-around the CGIAR funding crisis??
World population growth

**Current growth rate is ~73 million / year**

2000 - 6 Billion

2020 - 7.5 Billion

2050 - 8.9 Billion

2300 - 9 Billion

*World population may stabilize at ~9 Billion*
*(current UN estimates)*

How can we achieve the ‘next’ Green Revolution??

Technology components??
- Precision Ag
- Sustainable Ag
- No-till management
- Integrated Pest Management
- Organic farming
- Conventional plant breeding
- Molecular genetics
- Genetic engineering and GM crops
- Mechanical engineering
- Changes in land and water-use
- Public and/or private research

Barriers to adoption??
- Intellectual property rights
- Public investments in R&D
- Technology access
- Technology acceptance
- Financial and educational issues
The Challenge:
Increases in cereal productivity are slowing

...for all cereals, in all regions, as result of changing policy measures, growing water shortages, reduced investments in research and infrastructure development.

U.S. and Europe are ready and able to meet increased demand for cereals up to 2020.

But after 2020?? New technologies will be needed!!

Our best options for the future??

Employ intensive agricultural practices on the ‘best’ lands; reduce and avoid use of marginal lands.

*Use all technologies at our disposal* to achieve and sustain high productivity levels in environmentally responsive and responsible areas. Increasing land area used for crop production is no longer an option.

Make technologies accessible to developing countries to reduce poverty at the local level

*“Hunger is not about the food supply, it’s about poverty”*

Historically, the great famines have not been caused by an absolute lack of food, but because a segment of society lacked the resources to buy food.
Can we make the next an ‘Evergreen’ Revolution??

Swaminathan –

‘….the concept of ‘evergreen revolution’ (is proposed) to stress the need for enhancing crop productivity without associated ecological or social harm. An evergreen revolution can be achieved only if we pay attention to pathways that can help to achieve revolutionary progress…..’

‘An evergreen revolution will blend frontier technologies with the ecological prudence of traditional communities to create technologies that are based on integrated natural resource management and that are location specific….’
But:

Developing local, or location specific, integrated technology packages for developing countries will require large $$ R&D investments!!

How can we support such efforts??

Public funds??

At expense of what current programs ??

Private companies??

Profitability and ‘return on investments’ ??