Parental Rice line Breeding and New Variety Breeding in Korea

Woon-Goo Ha
International Technical Cooperation Center
Rural Development Administration
<table>
<thead>
<tr>
<th>Year</th>
<th>Rice Consumption per Capita</th>
<th>Self-Sufficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td>37.6</td>
<td>165.7</td>
</tr>
<tr>
<td>1980</td>
<td>34.1</td>
<td>163.8</td>
</tr>
<tr>
<td>1987</td>
<td>28.0</td>
<td>159.2</td>
</tr>
<tr>
<td>1989</td>
<td>29.1</td>
<td>160.9</td>
</tr>
<tr>
<td>1991</td>
<td>30.4</td>
<td>160.5</td>
</tr>
<tr>
<td>1993</td>
<td>31.4</td>
<td>157.9</td>
</tr>
<tr>
<td>1995</td>
<td>26.4</td>
<td>156.1</td>
</tr>
<tr>
<td>1997</td>
<td>29.7</td>
<td>153.3</td>
</tr>
<tr>
<td>1999</td>
<td>31.1</td>
<td>145.5</td>
</tr>
<tr>
<td>2001</td>
<td>29.4</td>
<td>156.1</td>
</tr>
<tr>
<td>2003</td>
<td>31.4</td>
<td>153.3</td>
</tr>
<tr>
<td>2005</td>
<td>29.7</td>
<td>153.3</td>
</tr>
</tbody>
</table>
## Changes in Rice Acreage and National Average Milled Rice Yield During the Last Five Decades in Korea

<table>
<thead>
<tr>
<th>Year</th>
<th>Area (1,000 ha)</th>
<th>Yield (ton/ha)</th>
<th>Product. (1000 ton)</th>
<th>Consump. (kg/pers/yr)</th>
<th>Self-sufficiency(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965</td>
<td>1,228</td>
<td>2.85</td>
<td>3,501</td>
<td>121</td>
<td>101</td>
</tr>
<tr>
<td>1970</td>
<td>1,203</td>
<td>3.30</td>
<td>3,939</td>
<td>136</td>
<td>93</td>
</tr>
<tr>
<td>1975</td>
<td>1,218</td>
<td>3.86</td>
<td>4,669</td>
<td>123</td>
<td>95</td>
</tr>
<tr>
<td>1980</td>
<td>1,223</td>
<td>2.89</td>
<td>3,550</td>
<td>132</td>
<td>95</td>
</tr>
<tr>
<td>1985</td>
<td>1,237</td>
<td>4.56</td>
<td>5,625</td>
<td>128</td>
<td>103</td>
</tr>
<tr>
<td>1990</td>
<td>1,244</td>
<td>4.51</td>
<td>5,606</td>
<td>120</td>
<td>108</td>
</tr>
<tr>
<td>1995</td>
<td>1,056</td>
<td>4.45</td>
<td>4,695</td>
<td>107</td>
<td>91</td>
</tr>
<tr>
<td>2000</td>
<td>1,072</td>
<td>4.97</td>
<td>5,291</td>
<td>93</td>
<td>103</td>
</tr>
<tr>
<td>2005</td>
<td>980</td>
<td>4.90</td>
<td>4,768</td>
<td>81</td>
<td>102</td>
</tr>
<tr>
<td>2008</td>
<td>927</td>
<td>5.20</td>
<td>4,843</td>
<td>76</td>
<td>99</td>
</tr>
</tbody>
</table>
Rice Ecosystems

Rice is unique in its ability to grow in a wide range of hydrologic environments, some of which where other crops cannot grow.
Water Condition

- **Irrigated**
  - Leveled
  - Bunded fields with water control
  - Transplanted or direct seeded in puddled soil
  - Shallow flooded in anaerobic soil during crop growth

- **Rainfed**
  - Level to slightly sloping
  - Bunded fields
  - Non-continuous flooding
  - Water level < 50 cm
  - Transplanted or direct seeded on puddled or plowed dry soil
  - Aerobic or anaerobic soil
Water Condition

- **Upland**
  - Level to steeply sloping fields
  - Rarely flooded
  - Aerobic soil
  - Direct seeded - plowed dry soil/dibbled in wet nonpuddled soil

- **Flood Prone**
  - Level to slightly sloping
  - More than 10 days of medium to deep flooding (50 to 300 Cm)
  - Transplanted or direct seeded
  - Aerobic or anaerobic soil
  - Soil salinity or toxicity in tidal areas
Rice Breeding in Korea
CULTIVER  WILDRICE

Bad alleles -> Good alleles

ABOUT 10,000 YEARS NEEDED
ABOUT 6,000 YEARS NEEDED
The transformation from WILD PHOTATO to CULTIVAR required approximately 6,000 years.
The breeding is fold good Alleles!

PLANT BREEDING
Bad alleles →
Good alleles
Changing

No. of Alleles
30,000
WILDRICE CULTIVER
Folding of Effective Good Alleles
### Selection

#### Plant breeding

<table>
<thead>
<tr>
<th>Resistance</th>
<th>Yielding</th>
<th>Yielding</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>High Yielding</td>
<td>Low Yielding</td>
</tr>
<tr>
<td>S</td>
<td>High Yielding</td>
<td>Low Yielding</td>
</tr>
</tbody>
</table>

- **Resist-ance**
- **Yielding**
- **Plant breeding**
Plant Breeding Effect

- Evolution Directed by the Will of Man
- Genetic Adjustment to the Service of Man
- Adaptational Change by Gene-Substitution under Artificial selection
- Integrated Science with Related Sciences
- Grounded on Genetics
- Based on Agriculture and Society to be served
Progressive Breeding Methods for Increasing Yield Potential

- **Past and present**

<table>
<thead>
<tr>
<th>Parents</th>
<th>Inbred variety</th>
<th>Same group</th>
<th>Different varieties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>![ParentsSymbol]</td>
<td>![SameGroupSymbol]</td>
<td>![DifferentVarietiesSymbol]</td>
</tr>
<tr>
<td>Cultivar</td>
<td>Pure line</td>
<td>Intra-varietal hybrids</td>
<td>Within-group hybridization</td>
</tr>
<tr>
<td>Breeding method</td>
<td>Selfing (pure line)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phase</td>
<td>Past</td>
<td></td>
<td>Present</td>
</tr>
</tbody>
</table>
Progressive Breeding Methods for Increasing Yield Potential

Future

- **Same species, different groups**
  - $G_1 \times G_2$
  - Inter-varietal hybrids

- **Different subspecies, species, genus**
  - $S_1 \times S_2$
  - Distant hybrids
  - Between-group hybridization

- **Wide hybridization**
  - Present-future

- **Future**

- **Inter-varietal hybridization**
  - Present-future

- **Distant hybridization**
  - Future
Plant Improvement by Breeding

Sources of Genetic Variation
- Within species - native varieties cultivars
- Between species – close relative distant relatives

Mutagenesis
Hybridization
Gene Insertion

New Genetic Variation
Selection Desired Combinations of Characters
Evaluation Under Field Condition
New Cultivar

Multiplication and Distribution to Farmer’s

Crop management environment and constraints
Achievement of Plant Breeding in World

- Development of **Hybrid Variety**
- Successful Use of **Semi-dwarf Gene**
- Genetic **Resistance to Diseases and Insects**
- Application of Cytogenetics
- Exploitation of Genetic Resources
Limitation to Breeding Strategies

- Genetic Linkage
  - Limited introgression of genes from wild species
  - Difficult to detach undesirable genes closely linked

- Polygenes from Wild Populations
  - Difficult to utilize unadapted wild populations or different species

- Complex Traits
  - Difficult to access and to identify attendant components

- Difficulties Identifying Useful Mutants
  - Very low frequency, and difficulty in identifying
  - Long-Time Scale of Slow Procedures
Mass Selection
Pure Line Selection
Pedigree Breeding
Bulk Breeding Method
Single-seed Descent
Recurrent Selection
Back Cross Breeding
Additional method
Mass Selection

- Selection of individuals
- Sampling seed of selected individuals to plant next generation
- Oldest method of crop improvement with old local or purify existing variety
- Improvement of heterogeneous native populations or landraces
- Select and bulk few hundred to few thousand superior plants on the basis of phenotype
- Only those varieties that show genetic variation can be improved through mass selection.
Mass Selection

- Higher percentage of desirable genotypes
- Method can only be used in environments where trait is expressed - may not be suitable for off-season winter nurseries
- Effectiveness is function of heritability
- Manage field to enhance differences
  : eg. irrigate excessively to increase disease pressure
Mass Selection

- Grow population
- Allow random mating
- Harvest and bulk seed from desirable plants
- Plant new generation
- Repeat
Pureline selection

- Pureline is the progeny of a single, homozygous, self pollinated plant.

- Select a large number of plants whose individual progenies are tested and the best progeny is released as a variety.

- It is used to develop a variety from local selections, introductions and old pureline varieties.

- Pureline varieties are extremely uniform. Examples: Mtu1, Patni6, T22 (India)
Pedigree Selection

- The most popular breeding method in rice.
- Individual plants are selected starting with F2 (250-500).
- In the subsequent segregating generations their progenies are tested.
- Selection is practiced between and within progeny families.
- Data on reaction to diseases and insects and grain quality etc. are scored starting F4.
- When progenies become homozygous they are bulk harvested and promoted to yield trials.
# Pedigree Breeding Method

<table>
<thead>
<tr>
<th>Generation</th>
<th>Number of plants</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1</td>
<td></td>
<td>Select parents and cross</td>
</tr>
<tr>
<td>Year 2</td>
<td>F₁</td>
<td>50–100 Bulk seed; space plant for higher yield</td>
</tr>
<tr>
<td>Year 3</td>
<td>T₂</td>
<td>2,000–5,000 Space plant for easy visual selection</td>
</tr>
<tr>
<td>Year 4</td>
<td>F₃</td>
<td>200 Select and plant in spaced rows</td>
</tr>
<tr>
<td>Year 5</td>
<td>T₄</td>
<td>100 Identity superior rows; select 3–5 plants to establish family in progeny rows</td>
</tr>
<tr>
<td>Years 6–7</td>
<td>T₅–F₆</td>
<td>25–50 Establish family progeny rows; select individual plants to advance each generation</td>
</tr>
<tr>
<td>Year 8</td>
<td>T₇</td>
<td>15 Conduct preliminary yield trials; select individual plants to advance</td>
</tr>
<tr>
<td>Years 9–11</td>
<td>F₆–F₁₀</td>
<td>5–10 Conduct advanced yield trials with more replications and over locations and years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 Cultivar release</td>
</tr>
</tbody>
</table>
Pedigree Nursery
A pedigree record is kept

Naming of pedigree is based on the cross number and serial numbers of selected plants (YR 6900-256-3-1-3)

- Pedigree method is the most extensively used method for handling the segregating generations from crosses
- Majority of RDA bred elite lines and varieties have been developed by the pedigree method
Bulk Breeding Method

<table>
<thead>
<tr>
<th>Generation</th>
<th>Number of plants</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1</td>
<td>$P_1 \times P_2$</td>
<td>50–100</td>
</tr>
<tr>
<td>Year 2</td>
<td>$F_1$</td>
<td>2,000–3,000</td>
</tr>
<tr>
<td>Year 3</td>
<td>$F_2$</td>
<td>2,000–3,000</td>
</tr>
<tr>
<td>Year 4</td>
<td>$F_3$</td>
<td>2,000–3,000</td>
</tr>
<tr>
<td>Year 5</td>
<td>$F_4$</td>
<td>3,000–5,000</td>
</tr>
<tr>
<td>Year 6</td>
<td>$F_5$</td>
<td>300–500</td>
</tr>
<tr>
<td>Year 7</td>
<td>$F_6$</td>
<td>30–50</td>
</tr>
<tr>
<td>Years 9–11</td>
<td>$F_8$–$F_{10}$</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>
Bulk Breeding Method

- Procedure for inbreeding a segregating population until the desired level of homozygosity is reached
- Easy way to maintain populations
- Natural selection permitted to occur in target environment
- F2 and the subsequent generations are harvested as bulk with or without selection
- At the end of the bulking period (4-5 cycles) individual plants are selected and their progenies are evaluated
- It is not a popular method as it does not allow the concurrent screening for a number of diseases and insects as well as other quality and agronomic traits
Single Seed Descent Method

<table>
<thead>
<tr>
<th>Generation</th>
<th>Number of plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1</td>
<td>P₁ × P₂</td>
</tr>
<tr>
<td>Year 2</td>
<td>F₁</td>
</tr>
<tr>
<td>Year 3</td>
<td>F₂</td>
</tr>
<tr>
<td>Year 4</td>
<td>F₃</td>
</tr>
<tr>
<td>Year 5</td>
<td>F₄</td>
</tr>
<tr>
<td>Year 6</td>
<td>F₅</td>
</tr>
<tr>
<td>Year 7</td>
<td>F₆</td>
</tr>
<tr>
<td>Year 8</td>
<td>F₇</td>
</tr>
<tr>
<td>Years 9–11</td>
<td>F₈–F₁₀</td>
</tr>
</tbody>
</table>

**Action**

- Grow F₁ plants, harvest all F₂ seeds per plant
- Grow F₂ population, harvest one seed per plant
- Grow F₃ population, harvest one seed per plant
- Grow F₄ population, harvest one seed per plant
- Space-plant to grow F₅, select best single plants
- Grow F₅-derived plant rows
- In the F₆ generation (F₅:₆)
  - Yield Test in F₇ (F₅:7 rows)
- Yield Test in F₈ (F₅:8 rows)
- Yield Test in F₉ (F₅:9 rows)
- Large-scale seed increase for variety release
Single Seed Descent Method

- Easy way to maintain and inbreed
  (Very little record keeping, No selection )
- All genotypes are sampled
  - useful for random genetic studies
  - Natural selection does not influence population
- Well suited to off-season winter nurseries
- One seed from each from a large number of F2 plants of a cross and the subsequent generations is used to raise the next generation until F6/F7 generation
- It is possible to grow 3-4 generations in a year
- SSD is primarily used to develop mapping populations
Recurrent Selection

![Diagram showing the improvement of a character over three generations: C₀, C₁, and C₂.](chart)

- **Character being improved**: The horizontal axis represents the character being improved.
- **Number of plants**: The vertical axis represents the number of plants.
- The chart illustrates the progression of improvement from generation to generation with overlapping curves.
Recurrent Selection

- Families created
  - Parents crossed in all possible combinations

- Families and plants/families evaluated

- New set of superior parents selected

- Inter-mated in all possible combinations, forming next generation cycle -- improved
Recurrent Selection / Population Breeding

- Outstanding plants from F2 and/or other segregating generations are mated among themselves
- It provides ample opportunities for recombination and helps in the accumulation of desirable genes for quantitative traits
- Male sterility system must be used for attempting crosses
- This method is used primarily to improve the parental lines used in hybrid breeding at RDA
Single Gene Transfer:
Linkage Drag with Traditional Backcross Breeding
Backcross Breeding

Single Gene Transfer:
Genetic Engineering is a form of Backcrossing

Donor species

Resistance Gene

gene insertion

Transformable Plant

Transformed Plant
Backcross Breeding

Single Gene Transfer:
Genetic Engineering is a form of Backcrossing

Transformable Plant

Transformed Plant – typically poor agronomic type

Thus, backcross to commercial variety via traditional backcross breeding procedure
Backcross Breeding

- The hybrid and the progenies in the subsequent generations are repeatedly backcrossed to one of the original parents used in the cross.

- The objective of backcrosses method is to improve one or two specific defects of a high yielding variety.

- Recently, tungro resistance has been transferred from *O. rufipogon* by recurrent backcrossing to IR64.