Deep Water Rice Breeding

For breeders course on 21 Aug., 2002
Seiji Yanagihara
Cited from Catling 1992
<table>
<thead>
<tr>
<th>Plant Character</th>
<th>Irrigated</th>
<th>Rainfed</th>
<th>Tidal Wetland</th>
<th>DWR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant type</td>
<td>Dwarf, erect, stiff strawed</td>
<td>Variable</td>
<td>Medium to tall, robust, stiff strawed</td>
<td>Medium to tall, elongating</td>
</tr>
<tr>
<td>Plant length</td>
<td>80-120cm</td>
<td>120-140cm</td>
<td>150-180cm</td>
<td>150-200cm</td>
</tr>
<tr>
<td>Sustained water depth</td>
<td>5-15cm</td>
<td>10-50cm</td>
<td>20-70cm</td>
<td>50-100cm</td>
</tr>
<tr>
<td>Elongation</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Flowering</td>
<td>Insensitive</td>
<td>Sensitive</td>
<td>Sensitive</td>
<td>Sensitive</td>
</tr>
<tr>
<td>Growth duration</td>
<td>100-120</td>
<td>110-130</td>
<td>120-150</td>
<td>150-180</td>
</tr>
<tr>
<td>Drought tolerance</td>
<td>Poor</td>
<td>Good</td>
<td>Good</td>
<td>Very good</td>
</tr>
<tr>
<td>Submergence</td>
<td>Poor</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Modern cultivars</td>
<td>Many</td>
<td>Few</td>
<td>Few</td>
<td>Few</td>
</tr>
</tbody>
</table>
Appropriate Varietal Tolerance Mechanisms for Various Flooding Patterns

Flooding problem

Flash Flooding

Stagnant Flooding (slow rise)

Stagnant flooding (abrupt rise)

Tolerance Mechanism

Submergence

Elongation ability

Fast emergence
Necessary Information for Breeding

Varieties as donor

Genetic information of target traits
Submergence

Tolerance is dominant
At least three dominant genes, two had duplicate gene action, the third is complementary to either of the other two. Broad sense heritability was estimated low.

High narrow sense heritability at 0.79 with high general combining ability.

F1 showed higher mean survival rate; it means dominant.

Tran Duc Thach; 1994.
The gen responsible for submergence tolerance was allelic to one of the two complementary genes controlling elongation. 
Elongation was partially dominant over submergence tolerance. 
FR13A, Kurkaruppan and Thavalu possess the same dominant gene for submergence, while Goda Heenati has a recessive gene.

Mackill, D. J. 1996.
Sub-1 was detected on chr.9 by using IR40931-26, which has a donor as FR13A. IR40931/PI543851 showed single QTL at about 70% phenotypic variation.

Nandi, S, Subudhi, 1997
5 QTLs were found on chms. 6, 7, 9, 11, 12. One on chm. 9 was Sub-1. Another on chm. 11 was vicinity of Adh-1, Adh-2. Each of 4 out of 5 except Sub-1 explained more than 19% of phenotypic variation.
**Elongation**

- Supapoj, N.; 1977. Elongation si incomplete dominance or recessive

- Hamamura, K., 1979. Partially dominant with additive effect of polygene

- Nasiruddin, M.; 1982. More than two genes for internode elongation or 3-4 dominant genes

- Thakur, R, 1988. Two complementary genes for elongation at additive each other.

- Suge, H., 1988. F1 showed intermediate elongation ability. F2 showed 9:7 and if GA3 applied, it turned into 3:1

- Tripathi, R. S.. 1985. Early nodal differentiation is controlling by single dominant gene.

- Tran Duc Thach, 1994. The gene responsible for submergence tolerance was allelic to one of the two complementary genes controlling elongation. Elongation was partially dominant over submergence tolerance.

- Sripongpangkul, K. et al. 2000. QTLs for plant height increment by flooding were detected on chrms. 1,2,and4. They were also responsible for internodal length increment. One on chrm6 was vicinity of sd-1.

---

**Important thing for breeder is how to use it!**
Breeding Strategy
Target Traits 1

I. Common traits need in both elongating and submergence tolerant lines:

Yield

* Erect leaves: efficient utilization of light for better carbon assimilation
* Wide and thick leaves: efficient utilization of light for better carbon assimilation
* Length and weight of panicles: better yield but with a balance of culm strength
* High fertility: for better yield and less risks in unfavorable conditions
* Threshability: too much shattering must be avoided
* Response to inputs: generally advantageous but may not be practical for deep-water areas. Could be useful in flash-flood areas
* Awns: may be advantageous when bird damage is expected, though, not common
*** Seed dormancy: advantageous when lodging or high humidity prevail just before harvesting
# Target Traits 2

## I. Common traits need in both elongating and submergence tolerant lines:

### Survival

- **Early vegetative vigor:** to compete with weeds especially for direct seeding
- **Optimum tillering ability:** but should not be too many especially for elongating rice
- **Longer leaves:** fast coming out of water and efficient utilization of light for better carbon assimilation
- **Maturity:** depending on the climate of the target environment. About 150 d at IRRI
- **Photoperiod sensitivity:** depends on the climate of the target area
- **Tolerance to other soil stresses:** depends on target site
- **Drought:** Necessary for rainfed condition
- **Tolerance to pest:** depends on prevailing pests in target sites

### Economic

- **Hull and grain color:** depends on farmers’ preference but usually yellow hulls and light brown grains color are preferred
- **Grain quality:** less chalkiness is recommended but grain shape depends on farmers’ preference
- **Eating quality:** depends on farmers’ preferences
II. Elongating rice for shallow water and flash flooding

Survival

* Facultative elongation ability: elongate only with rising water under deep-water condition but remain dwarf otherwise.

Yield

* Lodging resistance: minimize yield loss and maintain grain quality

III. Elongation

Survival

* Slow elongation (5cm/day): common elongation ability
* Facultative elongation ability: elongate only with rising water under deep-water condition but remain dwarf otherwise.
** Fast elongation (10cm/day): for areas with rapid water increment

Yield

*** Kneeing ability: minimize yield loss and maintain grain quality
IV. Submergence

Survival

* Tolerance to single cycle submergence; basic submergence tolerance for 10-14 days

** Tolerance to series of flash-flooding: tolerance to either periodical or series of flash flooding in specific area, e.g. tidal flooding

** Glabrous leaf advantageous to turbid water

V. Submergence avoidance(excluding elongation)

Survival

* Plant height; useful than elongation ability for areas that commonly experience shallow flooding

Yield

* Lodging resistance: minimize yield loss and maintain grain quality
Method (conventional)

1. Pedigree?
2. Bulk breeding?
3. Or?
Facility

1. Screening field
   * Controlled
   * Uncontrolled

2. Field for observation or generation advancement
   * Normal field
   * Special facility for generation advancement
Breeding Activities at IRRI
Standard Screening Method for Elongation Ability at IRRI

Field: Deepwater pond

Transplanting: 21 DAS in DS
    21 DAS in WS

Treatment: 30 DAT in DS and WS

Water raise: 5cm/day up to 100 – 120cm

Control: IR11141, IR42436, Jalnidhi and Jalmagna as DWR
         IR42 as irrigated rice
28 DAT. Ready to Put Water.
Plant height in shallow irrigation condition

Fig.   Elongation Ability of Current germplasm of Deepwater Rice
DWR New Plant Type (ir42436)

Under IR condition

Under DW condition
Field Views

Traditional DWR under IR condition

Improved DWR under IR condition

DWR under IR condition
Standard Screening Method for Submergence Tolerance at IRRI

Field: Submergence tank (artificial pond)

Transplanting: 21DAS

Stage of treatment: 30 DAT or 30 DAS

Duration: up to 14 days at 100 – 120 cm

Control: FR13A, BKNFR76106 as tolerant
IR42, IR64, iR72 as irrigated rice
The Art of Killing Plants
Alternative

Shading
RGA (rapid Generation Advancement)
MAS techniques for salinity tolerance and related stresses

<table>
<thead>
<tr>
<th>Trait</th>
<th>Develop mapping Pop’n</th>
<th>Develop Pheno. Tech.</th>
<th>Pheno. pop’n</th>
<th>Study Genetics</th>
<th>Tagged genes/ QTL</th>
<th>Fine map</th>
<th>PCR based MAS</th>
<th>Test MAS</th>
<th>Demo. to NARES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photosen.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salinity Na-K ratio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P efficiency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Submergence</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elongation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Al tox. Tol.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fe tox. Tol.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zn effeciency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salinity Na exclusion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salinity Tissue Tol.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Mapping Work

Sripongpangkul et al. (2000)

Material:

IR74/Jalmagna

Method:

RFLP anchor markers and AFLP
Markers associated with submergence tolerance

Epistatic and main-effect QTLs affecting initial plant height

Main-effect QTLs affecting internodes elongation

Main-effect QTLs affecting leaf elongation

Pairwise epistatic loci affecting plant elongation
Markers associated with submergence tolerance

Main-effect QTLs affecting internode elongation

Main-effect QTLs affecting leaf elongation

Pairwise epistatic loci affecting plant elongation

Epistatic and main-effect QTLs affecting initial plant height

Sub1(t)

Markers associated with submergence tolerance

Pairwise epistatic loci affecting plant elongation
<table>
<thead>
<tr>
<th>YEAR</th>
<th>INGER</th>
<th>GHAG</th>
<th>PUSA</th>
<th>CRRI</th>
<th>ASSAM</th>
<th>PCR</th>
<th>CAM-BODIA</th>
<th>PHI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>31</td>
<td>31</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1994</td>
<td>29</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td>8</td>
<td>46</td>
<td>48</td>
<td>44</td>
<td>43</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td>12</td>
<td>106</td>
<td>108</td>
<td>100</td>
<td>102</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td>35</td>
<td>32</td>
<td>104</td>
<td>104</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td>36</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>9</td>
<td>9</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>36</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>106</td>
<td></td>
</tr>
</tbody>
</table>
Good News
Fig. Pedigree of Prachinburi 2

(From Huntra Rice Research station and modified by Yanagihara)
Now Your Turn