BREEDING OF HIGH-YIELDING RICE VARIETIES IN JAPAN

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ABSTRACT
There are two major series of projects for the breeding of high-yielding rice varieties in Japan. The first series of projects are so called “Super Rice projects” in which we tried to develop super high yielding rice varieties by using a wider genetic background of rice varieties including Indica type rice. They were initiated in the beginning of 1980s and completed in the middle of 1990s. Before them the usages of Indica genetic resources were limited in Japan. Through the first projects the usage of Indica types was advanced and we developed varieties like Takanari and Akenohoshi. The second series of projects were started around year 2000 and have been continued to the present. The main purpose of those projects is to develop the varieties for animal feed. Over-production of rice has been a problem for the past 40 years in Japan. On the other hand, there is also a need for an increase in the production of domestic grain and bulk feed in Japan. Grain feed and whole crop silage (WCS) rice for bulk feed have being promoted by the government. For WCS the whole aerial parts consisting of grains, leaves and stems are harvested at the yellow ripening stage. At present, about 24 grain feed and WCS rice varieties have been bred and are commonly used in Japan. More than 8ton/ha grain yields have been achieved by several high yielding varieties such as Mochidawara, Hokuriku 193 and Momiroman. Their yields are up to 38 percent higher than control ordinary rice varieties for human. For WCS the total digestible nutrients (TDN) yields were around 12ton/ha which were similar to the yield of forage maize. Their TDN yields were 3 to 27% higher than those of ordinary rice varieties. The lodging resistances of most of the grain feed and WCS varieties are “High” and this trait is essentially important. By using a larger amount of fertilizer or manure application than ordinary rice varieties for human, those high yielding varieties can achieve high yields of grain and whole crop. Varieties for animal feed have wider genetic background and their ratios of Indica and Japonica vary from one variety to another.

KEYWORDS
High-yielding rice, grain yield, total digestible nutrients (TDN) yield, animal feed, lodging resistance, Indica and Japonica

REFERENCES
Breeding of High-yielding Rice Varieties in Japan

National Agriculture and Food Research Organization (NARO)
National Institute of Crop Science (NICS)
Animal Feed Rice Breeding Project, Project Leader
Hiroshi Kato

Rice production in Japan

Maximum amount was 14.25 million tons (1969)

Breeding of High-yielding Rice Varieties in Japan

Rice cultivated area

Maximum cultivated area was 3.17 million ha (1969)

Animal feed rice utilization in East Asian countries

Japan (Brown rice) 74.6 kg (1985) → 64.6 kg (2000) → 61.0 kg (2005)
Korea (Brown rice) 128.1 kg (1985) → 93.6 kg (2000) → 80.7 kg (2005)
China (Total grain in cities) 137 kg (1985) → 89 kg (1995) → 78 kg (2005)
Taiwan (Brown rice) 48.6 kg (2004)

Studies in animal feed rice

Japan: started in 2000
Korea: started in 2003, collaboration with Japan since 2003
China: rice grain has been used for grain feed when it is overproduced.
Malaysia: started in 2007
Animal Science Congress of the Asian-Australian Association 2006 (Busan), 2008 (Hanoi)
Japan-China animal feed meeting 2009 (Huanan)
Japan-Korea Symposium 2010 (Cheonan)

History of high-yielding rice breeding in Japan

1973: World wide shortage of animal feed grain
Arborio (Italian big-grain), Milyan23 (Korean Indica)
1982: “Super Rice Project” by using wider genetic background
Akenohoshi, Habataki, Takanari
1994: Projects ceased completely
2000: High-yielding project revived as the breeding of animal feed rice (Whole crop silage (WCS) rice)
Hoshiaoba, Kusahonami, Bekoaoba, Leaf Star
2008: Breeding of high-yielding rice for grain feed began
Momiroman, Mizuhochikara, Hokuriku193

Grain feed
Whole crop silage (WCS)
Rice straw

Crop is harvested at the yellow ripening stage. At this stage total digestible nutrients (TDN) is highest.
Subsidies in 2011 for 1ha cultivation of WCS or grain feed rice is ¥800,000 ($10,000).
**Types of animal feed rice**

- WCS
  - For cattle
- Grain feed
  - For cattle, pigs, poultry
- Stem and leaf yield type
  - Leaf Star
  - Tachisugata
  - Tachiaoba
  - Kusahonami
  - Yumeaoba
  - Mogumoguaoba
  - Hokuriku193
  - Momiroman
  - Mochidawara

**Breeding objectives of brown rice yield type rice**

Grain can be used as brown rice, unhulled rice and soft grain silage.

*Brown rice yield over 10t/ha*

<table>
<thead>
<tr>
<th>Variety</th>
<th>Heading Date</th>
<th>Maturity Date</th>
<th>Spike Length (cm)</th>
<th>Rough brown rice (kg/10a) (%)</th>
<th>Brown rice (kg/10a) (%)</th>
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<td>72</td>
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<td>90</td>
<td>596</td>
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</table>

**Low grain quality**

To prevent dishonest selling

**Herbicide sensitivity of rice varieties**

(benzobicyclon)

**Nipponbare**

**Takanari**

**Momiroman**
Important traits for the breeding of grain feed rice

Strengthened insect pest, lodging and cold tolerance:
- White-backed plant hopper
- Rice stripe
- Hot temperature

Higher grain yield:
- Panicle weight type
- Long growth duration
- Strong culm

Additional value and distinguishable traits:
- Black or red rice
- Sensitivity to herbicides
- Low grain quality or different shape

Breeding objectives of WCS rice

Whole crop yield
Total digestible nutrients (TDN) yield

Dry weight 22t/ha
TDN yield 13t/ha

Tachisugata
Tachisugata

Tachiaoba
Tachiaoba

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<th>Maturity Days</th>
<th>Culm Length (cm)</th>
<th>Whole Crop Yield (t/ha)</th>
<th>Grain Yield (t/ha)</th>
<th>TDN Content (%)</th>
<th>TDN Total (t/ha)</th>
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<td>56.5</td>
<td>1.01</td>
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Tachisuzuka

Kusanohoshi

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Kusanohoshi 8.29 8.29 8.29 8.29 11.03 11.03 11.03 11.03 1.78 1.78 1.78 1.78 0.72 0.72 0.72 0.72 56.85 56.85 56.85 56.85 1.01 1.01 1.01 1.01

Percentages of TDN and grain excretion of WCS dry matter for Holstein steers feed

Leaf Star

Lignin contents are lower than other varieties.

Long and strong culm and small panicle.

Leaf Star

Lignin contents are lower than other varieties.

Nonstructural carbon hydrate in stem and leaf sheath (%)

Leaves and Stars

Variety Variety Variety Variety Heading Heading Heading Heading Maturity Maturity Maturity Maturity Culm Culm Culm Culm Whole Crop Whole Crop Whole Crop Whole Crop Brown Brown Brown Brown TDNTDN TDNTDN TDNTDN TDNTDN Ratio Ratio Ratio Ratio Date Date Date Date Date Date Date Date Length(cm) Length(cm) Length(cm) Length(cm) Yield Yield Yield Yield Rice Yield Rice Yield Rice Yield content content content content Yield Yield Yield Yield

Leaf Star 8.31 8.31 8.31 8.31 10.16 10.16 10.16 10.16 1.92 1.92 1.92 1.92 0.42 0.42 0.42 0.42 61.06 61.06 61.06 61.06 1.17 1.17 1.17 1.17

Hamasari 8.31 8.31 8.31 8.31 10.08 10.08 10.08 10.08 1.73 1.73 1.73 1.73 0.51 0.51 0.51 0.51 60.76 60.76 60.76 60.76 1.05 1.05 1.05 1.05

Nipponbare

Leaf Star

Lignin contents are lower than other varieties.

Long and strong culm and small panicle.
**Important traits for the breeding of WCS rice**

- Strengthened insect pest, lodging and cold tolerance:
  - White-backed plant hopper
  - Rice stripe
  - Hot temperature

- Higher WCS yield:
  - Long culm in addition to small panicle
  - Strong culm
  - High NSC

- Additional value:
  - Low lignin
  - Small panicle or no grain
  - Low β carotene

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**Categorization of genomic regions to ‘Indica’ and ‘Japonica’ type**

Representative of Indica:
- IR8, IR24, Guichao2

Representative of Japonica:
- Nipponbare, Sas-anishiki, Koshikidari

2049 SNPs: 496

**Indica genome ratio in Japanese high-yield rice**

- Lemont (Japonica)
- Suweon258 (Indica)

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**「Rayada」**