BREEDING OF HIGH-YIELDING RICE VARIETIES IN JAPAN

Hiroshi Kato
NARO Institute of Crop Science

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

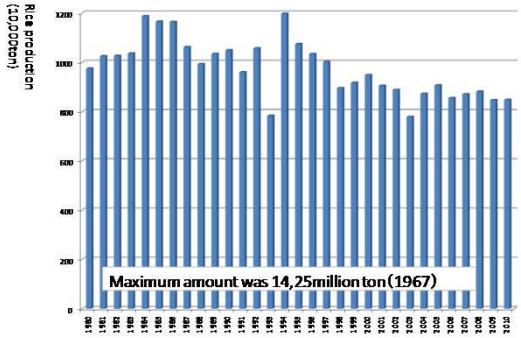
REFERENCES

Development of rice varieties for Whole Crop Silage (WCS) in Japan. Kato, H. 2008: JARQ 42, 231-236

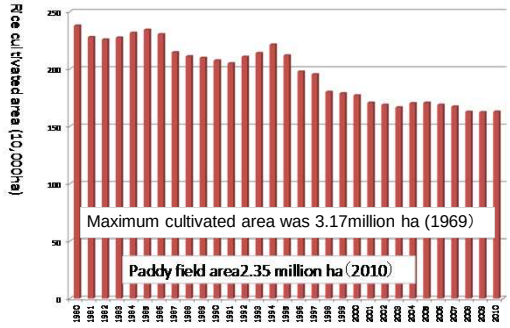
Breeding of High-yielding Rice Varieties in Japan

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



Rice cultivated area



Animal feed rice utilization in East Asian countries

Annual rice consumption/person

- Japan (Brown rice) 74.6kg(1985)→64.6kg(2000)→61.0kg(2005)
- Korea (Brown rice) 128.1kg(1985)→93.6kg(2000)→80.7kg(2005)
- China(Total grain in cities) 137kg(1985)→99kg(1995)→78kg(2005)
- Taiwan(Brown rice) 48.6kg(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

Japan, China and Korea International symposium for animal feed rice (2007) Beijing

History of high-yielding rice breeding in Japan

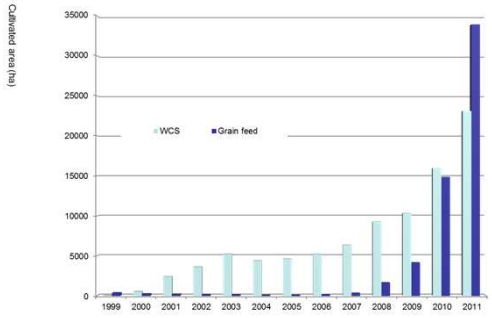
1973 : World wide shortage of animal feed grain
Arborio (Italian big-grain), Milyan23 (Korean Indica)
1982 : "Super Rice Project" by using wider genetic background
Akenohoshi, Habataki, Takanari
1994 : Projects ceased completely
2000 : High-yielding project revived as the breeding of animal feed rice
(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) Crop is harvested at the yellow ripening stage. At this stage total digestible nutrients (TDN) is highest.

Rice straw

Rice cultivation area for WCS and grain feed



農研機構

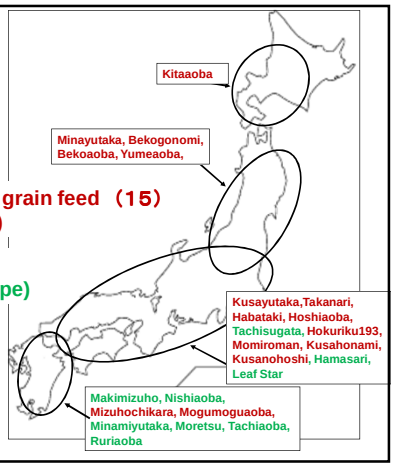
Subsidies for WCS
(since 1998)

Subsidies for Grain feed
(since 2007)

- Subsidies in 2011 for 1ha cultivation of WCS or grain feed rice is ¥800,000 ($10,000).

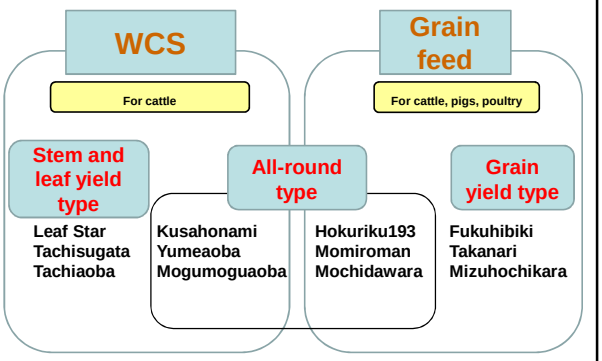
Varieties for WCS and grain feed （15）
(Brown rice yield type)

Varieties for WCS（9）
(Stem and leaf yield type)



Variety	Lodging resistance
Kitaaoba	Slightly low
Tachiiyoubu	High
Minayutaka	High
Bekogonomi	High
Natsuaoba	High
Fukuhibiki	High
Bekoaoba	High
Yumeaoba	Very high
Yumesakari	High
Makimizuho	Slightly high
Takanari	Very high
Hoshiaoba	Slightly high
Tachisugata	High
Mochidawara	Very high
Hokuriku193	Very high
Momiroman	Very high
Minamiyutaka	High
Mizuhochikara	Very high
Mogumoguaoba	High
Kusahonami	High
Kusanohoshi	Slightly high
Hamasari	High
Leaf Star	High
Tachisuzuka	Very high
Ruriaoba	Low
Tachiaoba	Very high
Ordinary rice varieties	
Nipponbare	Slightly high
Nishihomare	Slightly high
Koshihikari	Very low

Types of animal feed rice



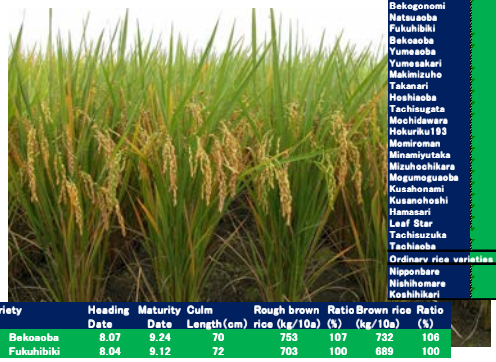
Breeding objectives of brown rice yield type rice

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

Brown rice yield over 10t/ha

「Bekoaoba」

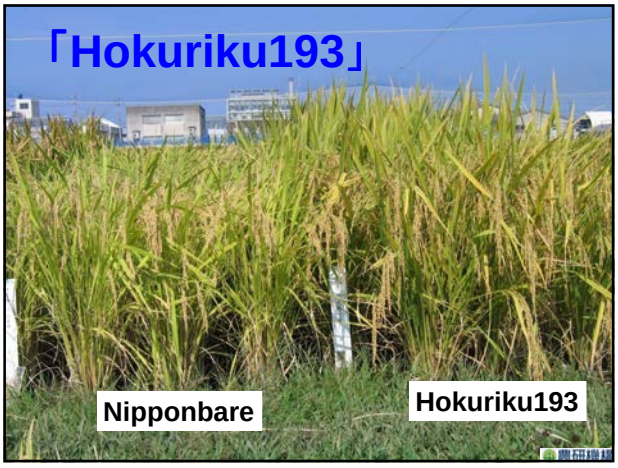
「Bekoaoba」



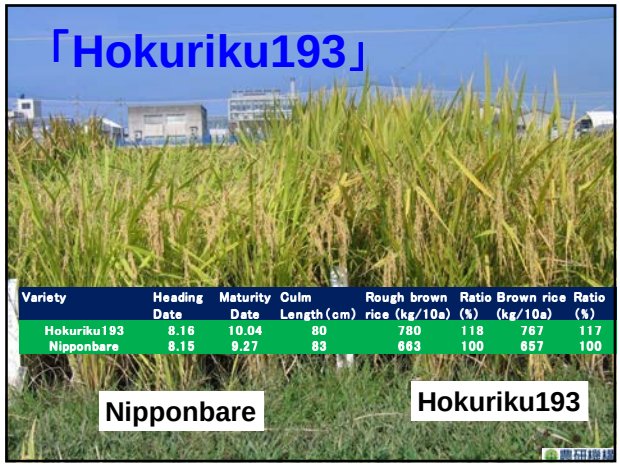
Variety	1,000-brown rice weight (g)
Kitaaoba	21.7
Tachijyoubu	21.8
Minayutaka	22.1
Bekogonomi	22.0
Natsuaoba	23.9
Fukuhibiki	23.2
Bekoaoba	30.6
Yumeaoba	26.5
Yumesakari	26.1
Makimizuho	36.5
Takanari	21.0
Hoshiaoba	29.4
Tachisugata	25.1
Mochidawara	22.7
Hokuriku193	22.9
Momiroman	24.1
Minamiyutaka	17.2
Mizuhochikara	23.0
Mogumoguaoba	29.1
Kusahonami	21.7
Kusanohoshi	24.3
Hamasari	18.4
Leaf Star	20.3
Tachisuzuka	21.5
Tachiaoba	22.2
Ordinary rice varieties	
Nipponbare	20.4
Nishihomare	21.2
Koshihikari	20.8

Variety	Heading Date	Maturity Date	Culm Length (cm)	Rough brown rice (kg/10a)	Ratio (%)	Brown rice (kg/10a)	Ratio (%)
Bekoaoba	8.07	9.24	70	753	107	732	106
Fukuhibiki	8.04	9.12	72	703	100	689	100

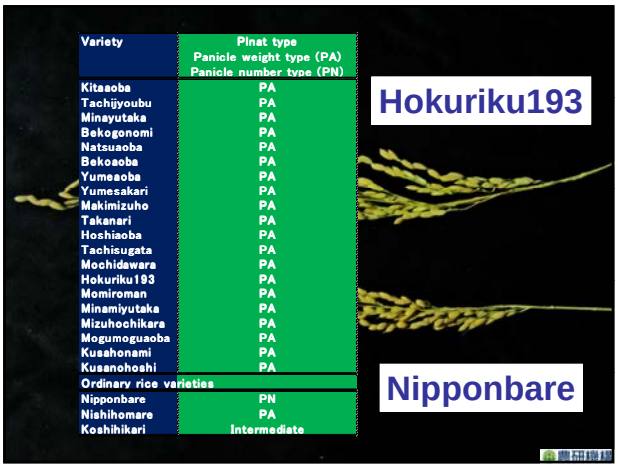
「Hokuriku193」



「Hokuriku193」



Variety	Heading Date	Maturity Date	Culm Length (cm)	Rough brown rice (kg/10a)	Ratio (%)	Brown rice (kg/10a)	Ratio (%)
Hokuriku193	8.16	10.04	80	780	118	767	117
Nipponbare	8.15	9.27	83	663	100	657	100

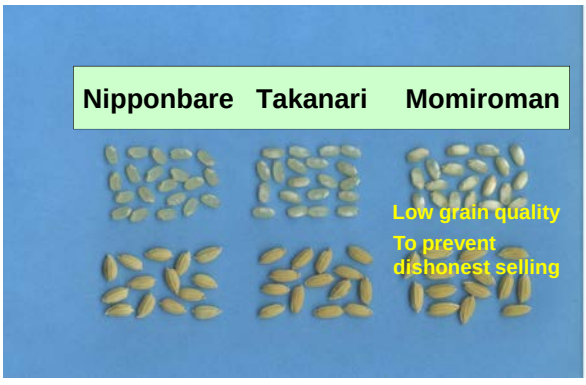


Variety	Pinat type Panicle weight type (PA) Panicle number type (PN)
Kitaaoba	PA
Tachiiyoubu	PA
Minayutaka	PA
Bekogonomi	PA
Natsuaoba	PA
Bekoaoba	PA
Yumeaoba	PA
Yumesakari	PA
Makimizuho	PA
Takanari	PA
Hoshiaoba	PA
Tachisugata	PA
Mochidawara	PA
Hokuriku193	PA
Momiroman	PA
Minamiyutaka	PA
Mizuhochikara	PA
Mogumoguaoba	PA
Kusahonami	PA
Kusanohoshi	PA
Ordinary rice varieties	
Nipponbare	PN
Nishihomare	PA
Koshihikari	Intermediate

「Momiroman」

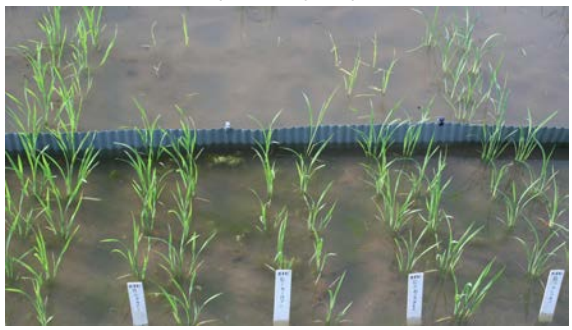
「Momiroman」

Variety	Heading Date	Maturity Date	Culm Length (cm)	Rough brown rice (kg/10a)	Ratio (%)	Brown rice (kg/10a)	Ratio (%)
Momiromann	8.15	10.09	89	823	138	765	132
Nipponbare	8.17	9.27	90	596	100	581	100



Herbicide sensitivity of rice varieties

(benzobicyclon)



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

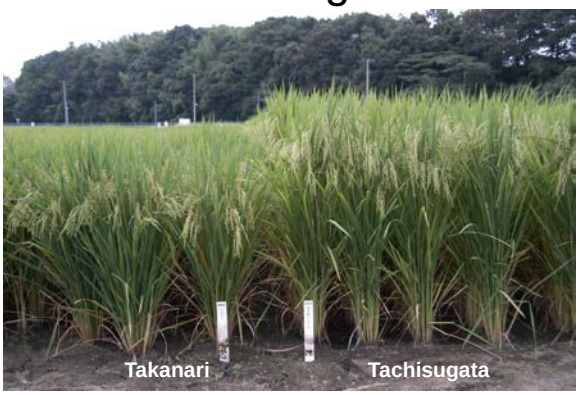
Whole crop yield

Total digestible nutrients (TDN) yield

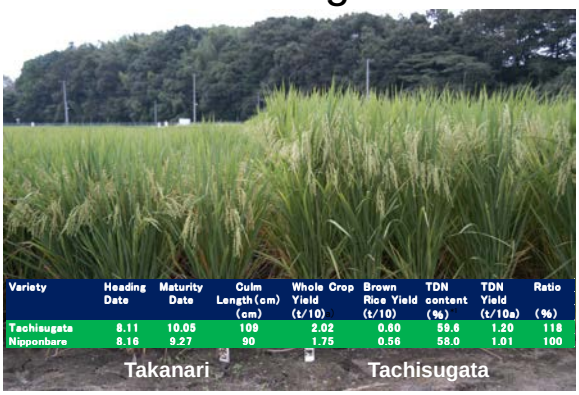
Dry weight 22t/ha

TDN yield 13t/ha

Tachisugata



Tachisugata



Variety	Heading Date	Maturity Date	Culm Length (cm)	Whole Crop Yield (t/10)	Brown Rice Yield (t/10)	TDN content (%)	TDN Yield (t/10a)	Ratio (%)
Tachisugata	8.11	10.05	109	2.02	0.80	59.6	1.20	118
Nipponbare	8.16	9.27	90	1.75	0.56	58.0	1.01	100

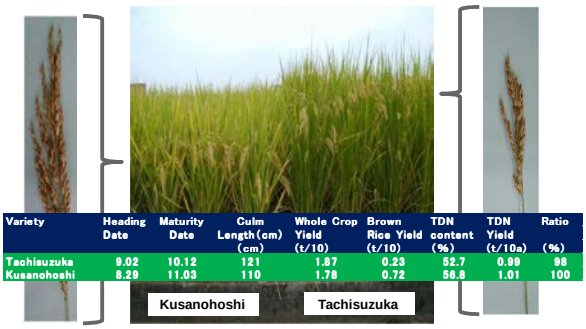
Tachiaoba

Tachiaoba

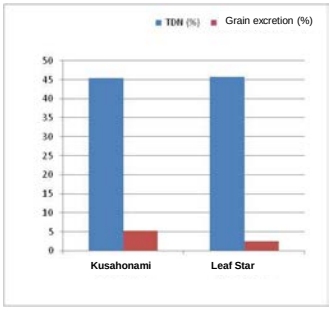
Variety	Heading Date	Maturity Date	Culm Length (cm)	Whole Crop Yield (t/10)	Brown Rice Yield (t/10)	TDN content (%)	TDN Yield (t/10a)	Ratio (%)
Tachiaoba	8.29	10.19	106	2.13	0.66	59.5	1.27	127
Minamihikari	8.25	10.09	86	1.69	0.56	59.5	1.00	100

「Tachisuzuka」

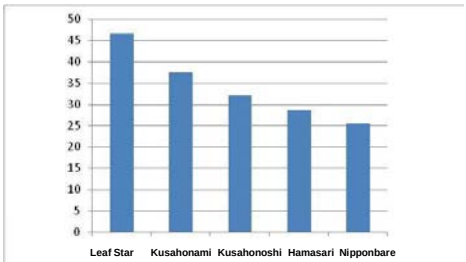
「Tachisuzuka」



Variety	Heading Date	Maturity Date	Culm Length (cm) (cm)	Whole Crop Yield (t/10)	Brown Rice Yield (t/10)	TDN content (%)	TDN Yield (t/10a)	Ratio (%)
Tachisuzuka	9.02	10.12	121	1.87	0.23	52.7	0.99	98
Kusanohoshi	8.29	11.03	110	1.78	0.72	56.8	1.01	100



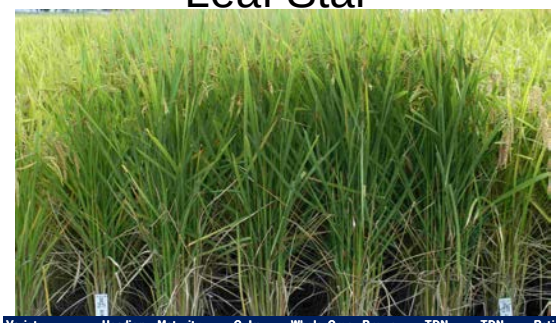
Percentages of TDN and grain excretion of WCS dry matter for Holstein steers feed



Nonstructural carbon hydrate in stem and leaf sheath (%)

Leaf Star

Leaf Star



Variety	Heading Date	Maturity Date	Culm Length (cm) (cm)	Whole Crop Yield (t/10)	Brown Rice Yield (t/10)	TDN content (%)	TDN Yield (t/10a)	Ratio (%)
Leaf Star	8.31	10.16	109	1.92	0.42	61.0	1.17	111
Hamasari	8.31	10.08	96	1.73	0.51	60.7	1.05	100

Kusahonami (Normal lignin content)

Lear Star (Low lignin content)

Important traits for the breeding of WCS rice

Strengthened insect pest, lodging and cold tolerance :

- White-backed plant hopper
- Rice stripe
- Hot temperature

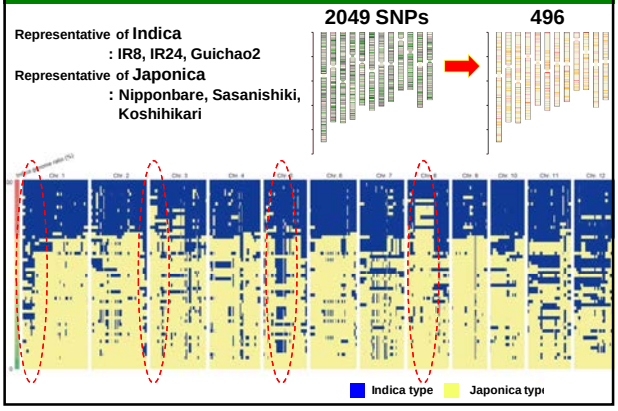
Higher WCS yield :

- Long culm in addition to small panicle
- Strong culm
- High NSC

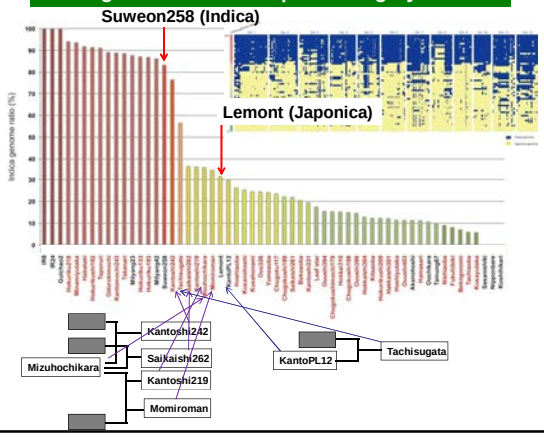
Additional value :

- Low lignin
- Small panicle or no grain
- Low β carotene

Categorization of genomic regions to 'Indica' and 'Japonica' type



Indica genome ratio in Japanese high-yield rice



「Rayada」