

Hokuriku 193: A New High-yielding Indica Rice Cultivar Bred in Japan

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Abstract

Hokuriku 193 is an indica rice cultivar released in Japan in 2007. It is characterized by a long panicle, a small number of panicles, a stiff culm, and a grain length typical of general indica rice cultivars. The mean brown rice yield of Hokuriku 193 was very high (7.65 t/ha) under experimental conditions during the period 1998 to 2005. The mean total air-dry weight was also very high at 20 t/ha. Hokuriku 193 is resistant to leaf and panicle blast and stripe virus and moderately resistant to bacterial leaf blast. It is expected to be useful worldwide not only as a staple food but also as a raw material for whole-crop silage and bioethanol production.

Discipline: Crop production

Additional key words: breeding, high-yield

Introduction

Food shortage is still a serious problem, and improvement of yield potential continues to be one of the most important objectives of rice breeding programs in developing countries. In contrast, since the mid 1980s, overproduction of rice has become a major concern in Japan; its cause has been an increase in yield accompanied by a gradual decrease in consumption. Under this circumstance, increasing attention has been paid in Japanese breeding programs to the identification of new genetic resources that will help widen the utilization of rice—from use of the grain as a food to use of the whole rice plant as a material for whole-crop silage (WCS) and bioethanol. There are many reports that some of the semi-dwarf indica rice cultivars have higher total dry matter production capacity than the japonica rice cultivars^{4,5}; the former are therefore considered useful for developing new cultivars suitable for WCS and bioethanol production. Some breeders have concentrated their efforts on improving total dry matter production by using semi-dwarf indica cultivars, and a few semi-dwarf indica rice cultivars (e.g. Habataki³, Yumetoiro⁶) have been released in the Hokuriku region. However, these cultivars are not sufficiently high yielding for WCS or bioethanol production.

In 1979 a semi-dwarf indica cultivar named Guizhao

2 was selected at the Guangdong Academy of Agricultural Sciences in China. Although it has the ability to yield very highly, further improvement was required for utilization of this capacity because of bad plant type and cultivation traits. As a result of continuous breeding using the progeny of crosses between Guizhao 2 and various lines, a very high-yielding indica cultivar, Hokuriku 193, was released in Japan in 2007. The maturation date of this cultivar makes it suitable for cultivation in the Hokuriku region, and the plant type and cultivation traits are better than those of the parental cultivar, Guizhao 2. Average brown rice yield of this cultivar is more than 7.5 t/ha at the experimental station, and a maximum yield of 9.0 t/ha has been achieved. And, in a trial, a total dry matter production of Hokuriku 193 was achieved to 20 t/ha. In short, the yield of Hokuriku 193 is very high in terms of both brown rice and total dry weight; the cultivar is expected to be useful globally not only as a staple food but also as a raw material for WCS and bioethanol production.

We briefly describe here the breeding process and some agronomic traits of Hokuriku 193.

Breeding Process

Hokuriku 193 originated from the progeny of a cross between Jou 344 and Guizhao 2 at the Hokuriku National Agricultural Experiment Station, Japan, in 2007 (Table 1,

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Fig. 1). Jou 344 is a line with short culms and long panicles that was selected from a cross between Suweon 258 and Hokuriku 133 at the Hokuriku National Agricultural Experiment Station. Suweon 258 is a short-culmed indica cultivar bred in Korea. Hokuriku 133 is a high-yielding line with short culms, selected from the cross Milyang 42 and Milyang 25 at the Hokuriku National Agricultural Experiment Station. Habataki³ and Takanari² were selected from the same cross as Hokuriku 133 and are also high-yielding cultivars. Although, Guizhao 2 is a very high-yielding cultivar with long panicles selected in China, this cultivar has spread culms and a habit of easy grain shattering; it is not suitable for common cultivation in Japan.

The cross was made in 1992 with the aim of com-

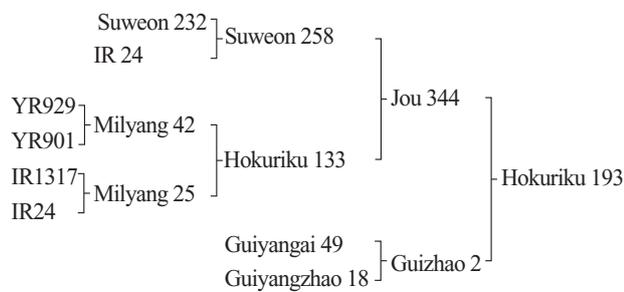


Fig. 1. Genealogy of Hokuriku 193

binning the high-yielding trait of Guizhao 2 with the plant type and other good cultivation traits of Jou 344. Fifty F₁ plants were grown in the field in summer 1993. The F₂ and F₃ bulk population was planted under direct seeding in the nursery bed in 1994–1995. In 1996, 2,320 F₄ plants were grown, from among which nine plants were selected. In the course of breeding operations, three F₅ lines from among the nine F₄ lines were identified for selection as promising materials for further yield tests. In 2000, one of the selected F₈ lines, named Hokuriku 193, proved to possess high-yielding ability under local adaptability tests at various locations in Japan. In 2007, registration of the line as a cultivar for public use in Japan was applied for.

Major agronomic characters of Hokuriku 193

1. Heading and maturation habit

The heading date of Hokuriku 193 is almost the same as that of Nipponbare and slightly later than that of Guizhao 2 (Table 2). Its maturation date is about 1 week later than Nipponbare and Guizhao 2. Therefore, Hokuriku 193 is regarded as a late cultivar in the Hokuriku region of Japan.

2. Plant type

Culm length, panicle length, and number of panicles per m² of Hokuriku 193 are, on average, about 80 cm, 29.0

Table 1. Selection records of Hokuriku 193

Year	1992–1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Generation	F ₀ –F ₃	F ₄	F ₅	F ₆	F ₇	F ₈	F ₉	F ₁₀	F ₁₁	F ₁₂	F ₁₃	F ₁₄
No. of line groups	Bulk			3	3	2	2	1	1	1	1	1
No. of lines (individuals)	Generation advance	(2,320) ^{a)}	9	15	15	10	10	5	5	5	10	10
No. of selected lines			3	3	2	2	1	1	1	1	1	1
No. of selected individuals		(9) ^{a)}	3	3	2	2	1	1	1	10	10	10

a): Individual selections. Others are line selections.

Table 2. Agronomic characters of Hokuriku 193 and control cultivars at the experimental station

Cultivar	Heading date	Maturation date	From heading to maturity (days)	Culm length (cm)	Panicle length (cm)	No. of panicles (/m ²)	Grain shattering index ^{a)} (3–7)	Lodging index ^{b)} (0–5)
Hokuriku 193	8.16	10.04	49	80	29.0	236	4.0	0.1
Nipponbare	8.15	9.27	43	83	20.7	398	3.0	1.0
Guizhao 2	8.14	9.27	44	82	23.3	279	7.0	0.7

Shown data is the average of experiments carried out between 1998 and 2005.

Seeding date: 4.15; Transplanting date: 5.16 (the average of experiments).

Plant spacing 18.5 plants/m².

Basal dressing: N 60, P₂O₅ 60, K₂O 60 kg/ha; topdressing: N 30, K₂O 41 kg/ha.

a): 3 (tolerant) to 7 (intolerant), b): 0 (None) to 5 (all).

cm, and 236, respectively (Table 2). The panicles are very long in comparison with those of the control cultivars; in contrast, there are fewer panicles than those of the controls. The leaves are erect and deep green. The culms are thick, stiff, and not so spread. The panicles bear a large number of long spikelets with few awns and yellow apiculi. The grains are semi-tolerant to shattering.

3. Grain size and quality

The 1,000-grain weight of Hokuriku 193 is 22.9 g for brown rice—almost the same as that of the control cultivars Nipponbare (23.3 g) and Guizhao 2 (23.0 g) (Table 3). The ratio of length to width of a brown rice grain is about 2.2, which corresponds to the grain ratio of indica rice cultivars generally. Hokuriku 193 has poorer grain quality than ordinary Japanese cultivars, but its quality is still better than those of other indica high-yielding cultivars such as Guizhao 2 (Table 3). Some of the grains of Hokuriku 193 have a white belly or white core. Hokuriku 193 is a nonglutinous cultivar. Its eating quality as a staple food is inferior to those of good-tasting Japanese cultivars,

such as Koshihikari and Hitomebore. The amylose content of Hokuriku 193 is about 15.4%—the same as, or lower than, those of other Japanese rice cultivars.

4. Yielding ability

Yield tests were carried out between 1998 and 2005 at the Hokuriku National Agricultural Experiment Station in Niigata Prefecture, one of Japan's rice production centers. In these tests, we applied fertilizer—N 60, P₂O₅ 60, K₂O 60 kg/ha—as a basal dressing before transplanting and N 30, K₂O 41 kg/ha as topdressing at the panicle initiation stage. The average total air-dry weight of Hokuriku 193 was 20.0 t/ha—about 13% higher than that of Nipponbare (Table 4). The average brown rice yield was 7.65 t/ha—about 17% higher than that of Nipponbare and still higher than that of Guizhao 2. The ratio of abortive kernels is lower than that in other indica cultivars such as Guizhao 2 and Yumetoiro.

In 2004 another yield test was conducted at the experiment station under conditions of high-level fertilizer application. In this test, we applied N 80, P₂O₅ 80, K₂O

Table 3. Characteristics of brown rice of Hokuriku 193 and control cultivars

Cultivar	1,000-kernel weight (g)	Grain appearance ^{a)}	Amylose content (%)	Grain length (mm)	Grain width (mm)	Length to width ratio
Hokuriku 193	22.9	5.8	15.4	6.2	2.8	2.21
Nipponbare	23.3	3.4	17.4	5.3	3.0	1.77
Guizhao 2	23.0	8.5	—	5.4	3.1	1.74

Shown data is the average of experiments carried out between 1998 and 2005.

a): 1 (superior) to 9 (inferior).

—: Not examined.

Table 4. Yielding ability of Hokuriku 193 and control cultivars at the experimental station

Cultivar	Total air-dry weight* (t/ha)	Brown rice weight (t/ha)	Ratio of aborting kernels (%)
Hokuriku 193	20.0±1.4 (113) ^a	7.65±0.48 (117) ^a	1.5
Nipponbare	17.8±0.8 (100) ^b	6.53±0.46 (100) ^b	0.7
Yumetoiro	17.5±1.2 (98) ^b	7.19±0.78 (110) ^{ab}	3.0
Guizhao 2	18.8±1.8 (106) ^{ab}	7.39±0.59 (113) ^{ab}	3.2

Shown data is the average of experiments carried out between 1998 and 2005.

Seeding date: 4.15; Transplanting date: 5.16 (the average of experiments).

Plant spacing 18.5 plants/m².

Basal dressing: N 60, P₂O₅ 60, K₂O 60 kg/ha; topdressing: N 30, K₂O 41 kg/ha.

Values are means of 8-year replicates ± SD.

Values in parentheses are relative to an assumed value of 100 for Nipponbare.

*: Weight of the whole plant, including rice straw and grains.

a, b: Means with the same letter within the same column are not significantly different at the 1% level of LSD.

80 kg/ha as a basal dressing before transplanting and N 40, K₂O 40 kg/ha as topdressing twice: 25 and 10 days before the heading date. A total dry weight of 20.1 t/ha was achieved for Hokuriku 193.

Extensive performance tests were undertaken from 2001 to 2005 in 21 prefectures covering the major rice producing areas of central Japan. The overall average brown rice yield of Hokuriku 193 was 6.96 t/ha—26% higher than those of control cultivars. The overall average total air-dry weight of Hokuriku 193 was 19.7 t/ha—30% higher than those of the control cultivars.

In a case study conducted in the Mitsuke area of Niigata Prefecture in 2007, a brown rice yield of 9.07 t/ha was achieved in Hokuriku 193 (Table 5). This test was conducted under high-level fertilizer application, and the high yield resulted from a high number of grains per panicle.

On the basis of these results, Hokuriku 193 may rate as the cultivar that possesses the highest yielding ability in terms of both brown rice and total dry matter among Japan's present rice cultivars. We therefore consider that this cultivar is suitable for utilization globally not only as a staple food but also as a raw material for WCS and bioethanol production.

Resistance to diseases, pests, and environmental stress

1. Resistance to diseases and pests

An analytical study of major genes resistant to leaf blast fungus showed that Hokuriku 193 possessed an unidentified true resistance gene to leaf blast (Table 6). Field resistance of this cultivar to leaf and panicle blast was examined in 1999 to 2006. No symptoms of either leaf or panicle blast were observed under the natural conditions of the paddy field. Field resistance of Hokuriku 193 to bacterial leaf blight was the same as that of Nipponbare and Koshihikari, both of which have moderately high field resistance to this disease. Hokuriku 193 has a resistance gene to rice stripe virus, but the same low resistance to stem borer as Guizhao 2.

2. Resistance to environmental stress

The cold resistance of Hokuriku 193 at the booting stage is lower than that of Koshihikari and higher than that of Akihikari (Table 7), and the new cultivar was therefore classified as moderately tolerant¹. The cold resistance of Hokuriku 193 at the flowering stage was lower than those of japonica rice cultivars and the same as that of Guizhao 2—in the moderately sensitive class¹.

The results of tests for sprouting in an incubator rated Hokuriku 193 in the tolerant class among rice cultivars.

Table 5. Yield components of Hokuriku 193 in tests conducted in the Mitsuke area of Niigata Prefecture in 1997

No. of panicles (/m ²)	No. of grains per panicle	No. of grains (/m ²)	Grain filling rate (%)	1,000-kernel weight (g)	Brown rice weight (t/ha)
269	162	43,500	89.0	23.8	9.07

Seeding date: 4.24, Transplanting date: 5.13, Heading date: 8.19.

Plant spacing: 18.3 plants/m².

Composted cow manure: 20 t/ha, basal dressing: N 44, P₂O₅ 44, K₂O 44 kg/ha, first topdressing: N 32 kg/ha, second topdressing: 39 kg/ha.

Table 6. Resistance to diseases and pests

Cultivar	Disease resistance				Resistance to stem borer	
	Blast resistance major gene	Blast field resistance		Bacterial leaf blight		
		Leaf	Panicle			
Hokuriku 193	unidentified	—*	—*	MR	R	S
Nipponbare	+	M	MR	MR	S	R
Guizhao 2	unidentified	—*	—*	—	—	S

R: Resistant, MR: Moderately resistant, M: Medium, S: Sensitive.

—*: Unable to judge because of unidentified resistance gene.

—: Not examined.

Table 7. Tolerance to environmental stress

Cultivar	Tolerance to cold at booting stage	Tolerance to cold at flowering stage	Tolerance to sprouting
Hokuriku 193	MT	MS	T
Nipponbare	MS	–	MS
Koshihikari	T	M	T
Akihikari	MS	T	MT
Guizhao 2	MT	MS	S

T: Tolerant, MT: Moderately tolerant, M: Medium, MS: Moderately sensitive, S: Sensitive.

–: Not examined.

Table 8. Agronomic characters of Hokuriku 193 and Hoshiaoba on direct-seeding cultivation at the experimental station

Cultivar	Year	Percentage establishment of seedlings (%)	Heading date	Culm length (cm)	Panicle length (cm)	No. of panicles (/m ²)	Total air-dry weight (t/ha)	Total rough rice weight (t/ha)	Lodging index ^{a)} (0–5)
Hokuriku 193	2005	13.8	8.22	72	28.8	346	12.9 (99)	6.4 (112)	0.0
	2006	7.5	8.24	82	35.0	220	11.9 (102)	5.9 (95)	0.0
	Average	10.6	8.23	77	31.9	283	12.4 (100)	6.1 (103)	0.0
Hoshiaoba	2005	46.3	8.12	78	21.0	294	13.1 (100)	5.7 (100)	0.0
	2006	15.0	8.15	83	23.6	180	11.7 (100)	6.2 (100)	0.0
	Average	30.6	8.13	81	22.3	237	12.4 (100)	5.9 (100)	0.0

Seeding date: 4.21 (2005), 4.20 (2006); seeding rate: 40 kg/ha.

Basal dressing: N 60, P₂O₅ 60, K₂O 60 kg/ha; topdressing: N 30, K₂O 41 kg/ha (2005), N 20, K₂O 27 kg/ha (2006).

Values in parentheses are relative to an assumed value of 100 for Nipponbare.

a): 0 (none) to 5 (all).

This might be related to the fact that the seeds of Hokuriku 193 have deep dormancy.

Adaptability and utilization

Taking into account its heading and maturing time, we expect that Hokuriku 193 will be grown for commercial purposes in a wide range of areas from Hokuriku to the southernmost parts of Kyushu. This wide adaptability was confirmed by the local adaptability tests, which covered major rice producing areas throughout the country. Because its heading time is late and its cold tolerance is not high, Hokuriku 193 is not suited for commercial production in colder areas of Japan such as Hokkaido, Tohoku, and the highlands.

Seeds of Hokuriku 193 have deep dormancy, and it is difficult for them to germinate until they are processed to break the dormancy by dry-heating. In direct-seeding cultivation tests, the percentage establishment of seedlings of this cultivar was very low—about 10%; this led to the

establishment of many weeds in the field (Table 8). Thus, Hokuriku 193 is probably not suitable for direct seeding, although the yield is not so bad.

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