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REVIEW

Breeding of Paddy Rice Varieties for Animal Feed in Warm Regions of Japan

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Abstract

In the Kyushu region, located in southern Japan, the area of paddy rice cultivated for whole- crop silage (WCS) and grain feed is increasing rapidly and has exceeded 8,000ha. At the Kyushu Okinawa Agricultural Research Center (KARC), various paddy rice varieties for WCS and grain feed have been developed in response to cultivation types in this region. “Makimizuho” is a WCS variety featuring early maturity and enabling cultivation in a dual-crop system. “Mogumoguaoba” is a variety with strong culm and high yield, making it usable for both WCS and grain feed. “Tachiaoba” is a high-yield variety for WCS with late maturity. “Ruriaoba” shows superior productivity under twice-harvested cultivation. “Mizuhochikara” is a variety with high grain yield and superior lodging resistance. These varieties are expected to help boost the feed self-sufficiency ratio in Kyushu.

Discipline: Plant breeding
Additional key words: grain feed, lodging, WCS, yield

Introduction

In Japan, the feed self-sufficiency ratio is only 25%, meaning there is considerable dependence on imports. However, their unstable prices and the need to improve the feed self-sufficiency ratio has boosted demand for domestic feed, hence the area of paddy field cultivated for feed has soared. In 1995, the area of paddy field used for WCS was only 23ha, but in 2010, the equivalent figure exceeded 15000ha, representing a more than 650-fold increase over fifteen years. In 2004, the area of paddy field used for grain feed was only 44ha, but reached 14000ha in 2010, an increase of more than 300 times in six years. While many paddy fields are fallow due to the overproduction of rice, the cultivation of livestock feed in paddy fields could improve the feed self-sufficiency ratio and make their use more effective. From this perspective, in Japan, paddy rice varieties for WCS have frequently been developed and used[3].

In Kyushu, located in southern Japan, rice and livestock have been raised in warm weather. The area of paddy fields cultivated for rice WCS in Kyushu accounts for 50% of its entire cultivated area in Japan and there is a high demand for domestic feed. There are various rice cultivation systems, such as the early-planting of culture and dual-crop system combined with wheat, barley and rushes, to meet the increasing demand for domestic WCS feed and grain feed, and there is a need to develop a rice variety adaptable for rice cultivation in this area. Moreover, other necessary traits for paddy rice for animal feed include high overall crop yields and grains, lodging resistance and disease and insect resistance.

Here, we cite the traits of four WCS and one grain feed variety developed in the Kyushu Okinawa Agricultural Research Center (KARC) and discuss the traits required for rice feed in future and the direction of breeding in this area.

Methods

To develop paddy rice varieties for WCS and grain feed, we conducted a yield trial involving the transplant of three different cropping types and direct seeding in flooded lowland fields at the KARC, Chikugo, Fukuoka Prefecture, Japan. A summary of this cultivation management is shown in Table 1, namely 1) early-planting

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culture, the object of which was to evaluate the traits of WCS breeding lines under a long planting period, 2) a common planting culture, the objective of which was to evaluate the traits of WCS breeding lines or grain feed for adaptability for a dual-crop system with wheat or barley and 3) late-planting culture, the objective of which was to evaluate the traits of WCS breeding lines of for adaptability for a dual-crop system with rushes. To measure the whole-crop and rough rice yield, forty hills were mowed manually during the yellow ripening stage in two replicates. To measure the brown rice yield, forty hills were mowed manually during the maturing stage in two replicates. The culm length, panicle length and number of panicles were measured as an average of ten plants in two replicates. The plant height was measured to the tip of the leaf length from the soil surface before the heading stage as an average of twenty plants in three replicates. The lodging degree was 0 for erect plants and 5 for plants with lodging, while the estimation of TDN (Total Digestible Nutrients) content was investigated on a dried matter basis by near-infrared spectroscopic analysis (NIR) at the National Institute of Livestock and Grassland Science.

"Makimizuho", which is a WCS variety with early maturity and adaptable to a dual-crop system

"Makimizuho" is a paddy rice variety for whole-crop silage with early maturity in the Kyushu region. The heading date in early-planting culture is in early August, for common planting culture in late August and for late-planting culture in late September (Fig. 1A, Table 2). In common planting culture "Makimizuho" was able to reach the yellow-ripening stage in late September. In the dual-crop system with wheat or barley, one of the key traits is the ability to reach the yellow-ripening stage within a short growing period. Because the ripening stage of "Hinohikari", the leading variety for human consumption in the Kyushu area, is early October, "Makimizuho" could be harvested earlier than "Hinohikari". The lodging resistance of "Makimizuho" also exceeds that of "Nipponbare", a staple variety with early maturity, and is equivalent to that of "Hoshiaoba"[5], a WCS variety with early maturity. In early-planting culture, the overall crop yield of "Makimizuho" is 26% heavier than that of "Nipponbare", while in common planting culture, the overall crop yield of "Makimizuho" is 23% heavier than that of "Nipponbare" and identical to "Hoshiaoba". In late-planting culture, the overall crop yield of "Makimizuho" is 71% heavier than that of "Nipponbare" and 4% less than that of "Hoshiaoba". In late-planting culture, the whole-crop or grain yield would decline due to the short growing period. However, the rate of decline of the overall crop yield of "Makimizuho" in late-planting culture is less than that of "Nipponbare", hence "Makimizuho" could adapt to a dual-crop system with various crops, such as wheat or barley, in a warm region of Japan. In direct seeding, the overall crop yield of "Makimizuho" is 29% heavier than that of "Nipponbare" and 8% heavier than that of "Hoshiaoba". The estimated TDN content of "Makimizuho" in early-planting culture is 56%, almost equivalent to that of "Nipponbare" and "Hoshiaoba". The TDN yield of "Makimizuho" is about 10t/ha in early-planting culture and 15% heavier than that of "Nipponbare", same as "Hoshiaoba". The rice blast true resistance gene of "Makimizuho" has not yet been estimated, while the field resistance of the rice blast of this variety cannot be estimated either, due to masking effect of those

Table 1. Summary of cultivation management for each cropping type

Cultivation type	Seeding date	Tarnsplanting date	Contents of fertilizer application(kg/a)			Planting pattern
			N	P	K	
Early-planting culture with heavy ferilizer	End of April	End of May	1.2	1.2	1.2	30cm×15cm
Early-planting culture with extra heavy fertilizer	End of April	End of May	1.8	1.8	1.8	30cm×15cm
Common planting culture with heavy fertilizer	End of May	End of June	1.6	1.2	1.9	30cm×16cm
Late-planting culture with heavy fertilizer	Early of July	End of July	1.2	1.2	1.2	30cm×15cm
Direct seeding in flooded lowland field	Early of June		1.0	0.8	1.0	

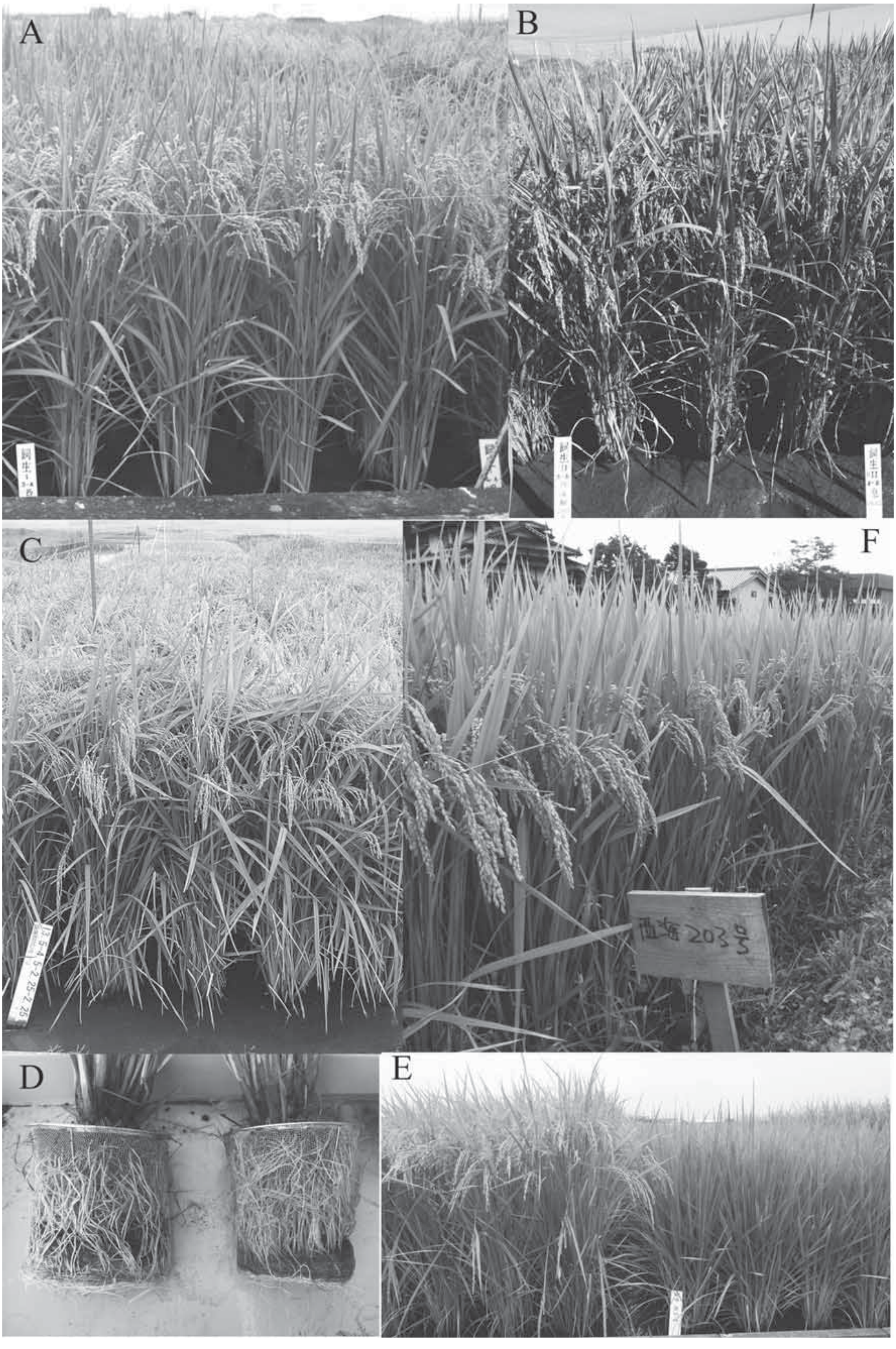

Fig.1. Plant appearance, (A) Makimizuho, (B) Mogumoguaoba, (C) Tachiaoba, (D) root of Tachiaoba (left) and Minamihikari (right), (E) plant appearance of first crop of Ruriaoba (left) and Tachiaoba (right), (F) Mizuhochikara

Table 2. Agronomic traits of “Makimizuho”

Cultivation	Year	Variety	Heading date	Yellow-ripe stage	Culm length (cm)	Length of panicles (cm)	Number of panicle (No/m^2)
Early-planting culture	2004-09	Makimizuho	8.04	9.08	103	22.4	214
		Nipponnbare	8.07	9.05	83	19.7	354
		Hoshiaoba	8.05	9.04	96	22.8	263
Common planting culture	2004-09	Makimizuho	8.23	9.25	102	23.4	213
		Nipponnbare	8.20	9.18	81	21.7	326
		Hoshiaoba	8.24	9.23	99	23.0	252
Late-planting culture	2007-09	Makimizuho	9.23	10.28	98	21.8	251
	2008	Nipponnbare	9.10	10.10	65	19.7	450
	2007-09	Hoshiaoba	9.24	10.28	90	20.6	312
Direct seeding	2005-08	Makimizuho	8.26	10.28	95	22.2	262
		Nipponnbare	8.22	—[d]	91	19.6	456
		Hoshiaoba	8.26	10.28	91	21.6	358

Cultivation	Year	Variety	Dry matter yield overall crop (t/ha)	Lodging degree[b]	TDN content[c] (%)	TDN yield (t/ha)
Early-planting culture	2004-09	Makimizuho	17.5	0.7	56.6	9.9
		Nipponnbare	13.9	0.9	58.2	8.6
		Hoshiaoba	17.2	0.5	56.7	9.8
Common planting culture	2004-09	Makimizuho	15.6	1.2	—[d]	—
		Nipponnbare	12.7	2.3	—	—
		Hoshiaoba	15.7	0.7	—	—
Late-planting culture	2007-09	Makimizuho	13.7	0.0	—	—
	2008-09	Nipponnbare	8.0	0.0	—	—
	2007-09	Hoshiaoba	14.4	0.0	—	—
Direct seeding	2005-08	Makimizuho	18.0[a]	2.1	—	—
		Nipponnbare	13.9[a]	3.3	—	—
		Hoshiaoba	16.7[a]	2.4	—	—

a): Air-dry yield.
b): Lodging degree was 0 for erect plants and 5 for plants with lodging.
c): Estimated formula is $TDN=16.651+1.495*(OCC+Oa)-0.012*(OCC+Oa)^2$, OCC(Organic cell contents), Oa(Organic a fraction in cell wall).
d): Not determined.

unknown genes. Resistance to bacterial leaf blight is “slightly weak”. “Makimizuho” is resistant to the rice stripe virus disease. It is important to distinguish rice varieties for feed from others. The grain shape of “Makimizuho” is huge and its culm length exceeds 1m, hence “Makimizuho” can be distinguished from rice varieties for human consumption.

“Mogumoguaoba”, which is useful both for WCS and grain feed with strong lodging resistance

“Mogumoguaoba” is a rice variety for both whole-crop silage and grain feed (Fig. 1B). The heading date in the early-planting culture of “Mogumoguaoba” is mid-August, while that for the common planting culture is early September. The yellow-ripening stage of “Mogu-

Table 3. Agronomic traits of “Mogumoguaoba”

Cultivation	Year	Variety	Heading date	Yellow-ripe stage	Culm length (cm)	Length of panicles (cm)	Number of panicle (No/m^2)	Dry matter yield: Overall crop (t/ha)	Dry matter yield: Straw (t/ha)	Dry matter yield: Rough rice (t/ha)
Early-planting culture with heavy fertilizer application	2004-08	Mogumoguaoba	8.17	9.20	104	21.3	248	19.2	12.7	6.5
		Nishihomare	8.18	9.20	93	19.6	371	15.3	10.5	5.2
		Nishiaoba	8.17	9.19	101	21.1	310	16.4	11.7	4.7
Early-planting culture with extra heavy fertilizer application	2005-08	Mogumoguaoba	8.18	9.19	103	22.9	251	18.6	11.8	6.8
		Nishihomare	8.22	9.23	98	21.6	331	14.2	9.6	4.6
		Nishiaoba	8.18	9.19	101	22.9	306	17.7	11.8	5.9
Common planting culture with heavy fertilizer application	2004-08	Mogumoguaoba	9.03	10.05	94	21.0	224	15.3	9.1	6.1
		Nishihomare	9.03	10.01	90	20.8	295	13.5	7.9	5.7
		Nishiaoba	9.03	9.30	94	20.5	297	13.5	8.3	5.2
Direct seeding	2006-08	Mogumoguaoba	9.02	—[d]	87	19.2	257	18.0[a]	9.5[a]	6.6[a]
		Kusanohoshi	9.04	—	78	19.0	197	14.0[a]	7.7[a]	5.4[a]

Cultivation	Year	Variety	Air-dry yield: brown rice (t/ha)	Lodging degree[b]	TDN content[c] (%)	TDN yield (t/ha)
Early-planting culture with heavy fertilizer application	2004-08	Mogumoguaoba	—	1.2	57.3	11.0
		Nishihomare	—	1.2	56.8	9.1
		Nishiaoba	—	2.3	58.1	10.0
Early-planting culture with extra heavy fertilizer application	2005-08	Mogumoguaoba	—	0.2	—	—
		Nishihomare	—	0.7	—	—
		Nishiaoba	—	2.8	—	—
Common planting culture with heavy fertilizer application	2004-08	Mogumoguaoba	7.2[e]	0.1	—	—
		Nishihomare	5.4[e]	1.8	—	—
		Nishiaoba	—	3.4	—	—
Direct seeding	2006-08	Mogumoguaoba	—	2.0	—	—
		Kusanohoshi	—	2.7	—	—

a): Air-dry yield.
b): Lodging degree was 0 for erect plants and 5 for plants with lodging.
c): Estimated formula is $TDN=16.651+1.495*(OCC+Oa)-0.012*(OCC+Oa)^2$, OCC(Organic cell contents), Oa(Organic a fraction in cell wall).
d): Not determined.
e): Examination year is 2007-08.

moguaoba” is early October in common planting. “Mogumoguaoba” has medium maturity and its key agricultural trait is strong lodging resistance. The stem of “Mogumoguaoba” is thick and hard and its lodging resistance of “Mogumoguaoba” is apparently stronger than that of “Nishiaoba”[11], which is a WCS variety with middle maturity (Table 3). The second key agricultural trait is the high overall yield. In early-planting culture the overall yield was 19t/ha, namely 17% heavier than that of “Nishiaoba”, while in common planting culture, the figure was 15t/ha, 13% heavier than. In direct seeding, the overall crop yield of “Mogumoguaoba” was 29% heavier than that of “Nishihomare”, which is a staple variety with middle maturity. The third key trait is its high brown rice yield. In common planting culture, it was 7.2t/ha, exceeding “Nishihomare” by 33%, while the brown rice yield cultivated in the adaptation test in 2009 exceeded 10t/ha (data not shown). "Mogumoguaoba" was also usable for grain feed. The estimated TDN content of "Mogumoguaoba" in early-planting culture is 57%, almost equivalent to those of "Nishihomare" and "Nishiaoba", while the TDN yield of "Mogumoguaoba" in early-planting culture was about 11t/ha, 21% heavier than that of "Nishihomare" and 10% heavier than that of "Nishiaoba". "Mogumoguaoba" could be cultivated in fertile lowland due to its strong lodging resistance. The rice blast true resistance gene of " Mogumoguaoba" is not estimated yet, while the field resistance of this variety of rice blast cannot be estimated due to the masking effect of unknown genes. Resistance to bacterial leaf blight is "moderate", although it is resistant to rice stripe virus disease. Since the grain shape of "Mogumoguaoba" is very large, it can be distinguished from that of the varieties for human consumption. "Mogumoguaoba" was available not only for whole crop silage but also grain feed.

"Tachiaoba", with high overall crop yield and late maturity

"Tachiaoba"[8] is a paddy rice variety for whole-crop silage with extra late maturity. The heading dates for the early- and common planting culture were late August and early to mid-September respectively. The yellow-ripening stage was early and mid-October respectively for the early-planting and common planting cultures (Fig. 1C, Table 4). "Tachiaoba" showed key agricultural traits for WCS, the first of which was its high overall crop yield and the second its strong lodging resistance. The crown root of "Tachiaoba" was apparently thicker than that of

Table 4. Agronomical traits of "Tachiaoba"

Cultivation	Year	Variety	Heading date	Yellow-ripe stage	Culm length (cm)	Length of panicle (cm)	Number of panicles (No/m^2)
Early-planting culture with heavy fertilizer application	2002-05	Tachiaoba	8.29	10.03	106	25.6	284
		Minamihikari	8.25	9.23	86	21.5	432
Early-planting culture with extra heavy fertilizer	2001-05	Tachiaoba	8.29	10.03	107	28.3	299
		Minamihikari	8.25	9.23	86	22.7	442
Common planting culture with heavy fertilizer application	2002-05	Tachiaoba	9.09	10.12	100	26.5	261
		Minamihikari	9.05	—[d)]	76	22.1	390
Direct seeding	2003-04	Tachiaoba	9.13	—	92	21.6	325
		Minamihikari	9.08	—	74	19.0	455

Cultivation	Year	Variety	Dry matter yield of overall crop (t/ha)	Lodging degree[b)]	TDN content[c)] (%)	TDN yield (t/ha)
Early-planting culture with heavy fertilizer application	2002-05	Tachiaoba	21.3	0.6	59.5	12.7
		Minamihikari	16.9	1.2	59.5	10.0
Early-planting culture with extra heavy fertilizer	2001-05	Tachiaoba	22.1	1.5	—	—
		Minamihikari	17.2	2.0	—	—
Common planting culture with heavy fertilizer application	2002-05	Tachiaoba	17.5	0.4	—	—
		Minamihikari	15.1	0.3	—	—
Direct seeding	2003-04	Tachiaoba	17.3[a)]	0.8	—	—
		Minamihikari	15.6[a)]	2.5	—	—

a): Air-dry yield.
b): Lodging degree was 0 for erect plants and 5 for plants with lodging.
c): Estimated formula is $TDN=16.651+1.495*(OCC+Oa)-0.012*(OCC+Oa)^2$, OCC(Organic cell contents), Oa(Organic a fraction in cell wall).
d): Not determined.

"Minamihikari" (Fig. 1D), while the culm length exceeded 1m, which is 20cm longer than the paddy rice variety "Minamihikari", a staple variety with late maturity. The lodging resistance also exceeded that of "Minamihikari". The overall crop yield in early-planting culture exceeded 20t/ha, while that for common planting culture was about 18t/ha (Table 4). In direct seeding, the overall crop yield of "Tachiaoba" exceeded that of "Minamihikari", while the estimated TDN content of "Tachiaoba" in early-planting culture was 60%, equivalent to that of "Minamihikari". The TDN yield of "Tachiaoba" was 12t/ha and 27% heavier than that of "Minamihikari". The rice blast true resistance gene of "Tachiaoba" was estimated as *Pia* and *Pii*. The field resistance to leaf blast and panicle blast were "medium" and "slightly strong" respectively, while the resistance to bacterial leaf blight was "slightly weak". "Tachiaoba" was resistant to rice stripe virus disease and adaptable to be cultivated in the fertile lowland of the Kyushu region.

"Ruriaoba", which is a WCS variety suitable for harvesting twice

"Ruriaoba" is a rice variety for whole-crop silage, with the high ratooning ability and suitable for a dual harvesting system, which was developed from "Taporuri", a local glutinous upland rice variety in Taiwan. It is known that the overall "Taporuri" crop has considerable growth but is also prone to shattering. Therefore we irradiated its seed with γ-rays and selected a plant with shattering resistance but otherwise sharing the same agricultural traits as "Taporuri". The heading date of "Ruriaoba" in the first crop was 7 days earlier than that of "Tachiaoba", while that in the second crop was 12 days later than that of "Tachiaoba". The lodging resistance of "Ruriaoba" was estimated as weak just like that of "Taporuri" (Table 5). The overall crop yield of the first crop of "Ruriaoba" was 11.3t/ha and that of the second crop was 11.5t/ha, hence the total crop yield for the dual harvesting of "Ruriaoba" was 22.8t/ha, exceeding "Tachiaoba" by 15%. The estimated TDN content of "Ruriaoba" in dual harvesting was not investigated. Nakano (2009) [6] reported that the estimated TDN content of "Tapururi" for the first and second crops was slightly lower than "Tachiaoba" but that the TDN yield of "Taporuri" in dual harvesting exceeded "Tachiaoba" by 7%. Because the agricultural traits of "Ruriaoba" were almost identical to "Taporuri" (Table 5), we speculated that the estimated TDN content and yield of "Ruriaoba" in dual harvesting were identical to "Taporuri". The lodging of "Ruriaoba" can be avoided by mowing at the full heading stage in the first harvesting, while the rice blast true resistance gene of "Ruriaoba" has not yet been estimated. The field resistance of rice blasts of this variety cannot be estimated due to the masking effect of unknown genes. Whereas resistance to bacterial leaf blight was "moderate", "Ruriaoba" is resistant to rice stripe virus disease.

"Mizuhochikara", which shows high grain yield and is useful for grain feed

"Mizuhochikara" is a rice grain feed variety, the breeding objective for which was to develop a high brown rice yield variety with strong culm. Its culm length was 76cm, making it 15cm shorter than that of "Nishihomare", while the panicle length of "Mizuhochikara" was 21.4cm, 1.5cm longer than that of "Nishihomare" and with a lower panicle number than the latter (Table 6). The flag leaf of "Mizuhochikara" was erect, with a good plant shape (Fig. 1F) and positive culm thickness. The heading date of "Mizuhochikara" for common planting culture was early September, classed as medium maturity in southern Japan, slightly later than that of "Nishihomare". The ripening stage of "Mizuhochikara" for both

Table 5. Agronomical traits of "Ruriaoba"

Cultivation	Year	Variety	Heading date	Plant height (cm)	Number of panicles (No/m²)	Dry matter yield of overall crop (kg/a)	Lodging degree[a)]
First crop	2007-08	Ruriaoba	8.05	155	331	11.3	2.5
		Taporuri	8.06	164	314	11.3	2.5
		Tachiaoba	8.12	117	296	11.3	0.0
Second crop	2007-08	Ruriaoba	9.30	142	413	11.5	2.5
		Taporuri	9.30	150	377	11.5	2.5
		Tachiaoba	9.18	91	426	8.5	0.0

a): Lodging degree was 0 for erect plants and 5 for plants with lodging.

Table 6. Agronomical traits of "Mizuhochikara"

Cultivation	Year	Variety	Heading date	Ripening stage	Culm length (cm)	Length of panicle (cm)	Number of panicles (No/m^2)	Yield of brown rice[a)] (t/ha)	Lodging degree[b)]
Common planting culture	1992-2008	Mizuhochikara	9.02	10.31	76	21.4	306	7.3	0.1
		Nishihomare	9.03	10.22	91	19.9	357	6.1	0.8
Direct seeding	2000-2008	Mizuhochikara	9.10	10.27	69	19.6	416	7.6	0.0
		Nishihomare	9.07	10.18	75	17.8	444	6.0	1.2

a): Air-dry yield.
b): Lodging degree was 0 for erect plants and 5 for plants with lodging.

early and common planting cultures was late October, classed as very late maturity. The lodging resistance of "Mizuhochikara" was very strong (Table 6), while its brown rice yield of "Mizuhochikara" for common planting culture was 7.3t/ha, 20% higher and that for direct seeding, 27% higher than that of "Nishihomare" respectively (Table 6). During an adaptability test conducted in Hiroshima prefecture, located in western Japan, the brown rice yield of "Mizuhochikara" was 10t/ha, while that in Ibaraki prefecture located in the east of Japan was 8.3t/ha (data not shown). From these results, "Mizuhochikara" was considered adaptable from eastern to southern Japan. Its grain length was identical to that of "Nishihomare", while its grain width and thickness both exceeded those of the latter. The grain appearance of "Mizuhochikara" was inferior to that of "Nishihomare" due to abundant white belly rice and milk white rice kernels, while its rice blast true resistance gene of "Mizuhochikara" has not yet been estimated. It was also impossible to estimate the field resistance of the rice blast of this variety due to the masking effect of unknown genes. Resistance to bacterial leaf blight was "weak" and "Mizuhochikara" suffers from virulent rice stripe virus disease.

Discussion

The four WCS varieties mentioned above would enable to the cultivation of domestic bulky feed in paddy rice throughout the Kyushu area. "Makimizuho" could be adaptable for a dual-crop system with wheat conducted in the northern part of this area. "Mogumoguaoba" could be cultivated in a fertile lowland due to its strong lodging resistance. "Tachiaoba" and "Ruriaoba", with their high overall crop yield, could be cultivated in southern Kyushu, where the rice cultivation period may be longer than that of northern Kyushu. "Mizuhochikara", however, is the only grain feed variety with intermediate maturity and which requires a long time to reach maturity, meaning it would not be adaptable to late-planting culture and there would be a need to develop a grain feed variety with early maturity in future. These WCS and grain feed varieties would then contribute to supply the domestic feed in Kyushu.

In rice whole-crop silage, the problem of some grains being discharged as indigestible in the dung of cattle has emerged. In response, attempts were made to develop a rice WCS variety with decreased rations of grain and straw. "Leaf Star"[4] is the paddy rice variety for WCS, with a grain and whole-crop weight ratio of 24%, namely less than that of the usual WCS variety. And in an examination during which dairy cattle were fed on rice made from "Leaf Star" and "Kusahonami"[7], the portion of undigested grains in the dung of the dairy cattle fed on "Leaf Star" was 2.8% less than those fed with on "Kusanohoshi"[10], which indicated that the development of a variety decreasing the potion of grain was effective in improving the digestibility of rice WCS. The next move in WCS rice breeding in Kyushu might be to develop a variety with decreased straw and grain ratios.

Rice cultivation in the Kyushu area is exposed to risks of the disease and insect damage. However, in Japan the use of chemicals with rice is strictly restricted and it is important to develop a variety tolerant to disease and insect pests. The rice blast true resistance genes for "Makimizuho", "Mogumoguaoba", "Ruriaoba" and "Mizuhochikara" have not yet been estimated, nor can the field resistance of such rice blasts be estimated due to the masking effect of unknown genes. Rice blast field resistance genes, such as *Pb1*[2] and *Pi21*[1], have, however, been isolated. Developing a rice variety with these genes introduced is key to reducing the risk of breakdown of true resistant genes due to the change of blast races. Brown planthopper (BPH) is a common insect pest affecting rice in the Kyushu area. More than ten resistance genes have been identified and used to develop the resistant varieties for BPH. However, some of these genes were reportedly rendered virulent due to a change of biotype. "KantoBPH-No.1" was developed to introduce *bph11*, which is derived from wild rice *Oryza officianlis* and it would be effective to develop a feed rice variety with *bph11*. Developing a feed rice variety which is resistant to diseases and insects is effective to reduce the cost of cultivation. Marker-assisted selection methods would be a powerful tool to develop such a feed rice variety.

Direct seeding might also be a useful method to reduce the cost of cultivation. Here, lodging resistance is a key trait. Four varieties, except "Ruriaoba" mentioned above, have strong culm and strong lodging resistance, meaning these could also be cultivated via direct seeding. During harvesting contamination of weeds in the forage could reduce the quality of rice WCS (personal communication), hence management of weeds is important during direct seeding of paddy rice for WCS. In Kyushu, however, the direct seeding of rice for WCS is rare due to damage caused by the apple snail, *Pomacea canaliculata*.

It has been reported that some Japanese rice feed varieties, such as "Ruriaoba" and "Mizuhochikara", are susceptible to herbicides, including benzobicyclon, tefuryltrione and mesotrione in components[9]. Farmers should be careful when using such herbicides, although they are also considered an effective means to remove the contaminated feed rice seedlings from paddy rice field cultivated staple rice varieties for human consumption.

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