Breeding Procedure of Non-malting, 2-Rowed Barley in Kyushu

By TOMIHIKO YOSHIDA*

First Crop Division, Kyushu National Agricultural Experiment Station

The area cropped to barley in the Kyushu region in 1978/79 growing season was about 45,000 ha, accounting for about 40% of the total barley acreage of Japan. About 60% of the area was planted to malting barley (2-rowed, hulled), 30% to barley for feeding and human consumption (2-rowed, hulled) and 10% to 6-rowed, naked barley for human consumption. All of them are winter barley. The 2-rowed barleys are widely grown mainly because of their scab resistance. Objective in breeding barley at Kyushu National Agricultural Experiment Station in Chikugo, Fukuoka Prefecture (hereafter the station is referred simply as Chikugo) is to develop high yielding, stiff straw, early maturing and disease resistant barleys for feeding and human consumption (non-malting barleys). In this paper, breeding procedure of 2-rowed barley at Chikugo will be outlined, with examples of developing an early maturing line, Saikai-kawa 24, and some BYMV resistant lines.

Early maturing Saikai-kawa 24

About 80% of barley is grown in lowland in Kyushu and is harvested before transplanting of rice. Therefore, early maturing of barley is an urgent necessity for barley growers in Kyushu. Saikai-kawa 24 was originally designed for a conventional fall sown, early maturing, stiff straw, disease resistant and high yielding variety.

1) Crossing and early generations

Saikai-kawa 24 originated from the cross Saikai-kawa 7/Asahi 5, which was made in 1967. Asahi 5 was one of the leading malting varieties in 1960s and Saikai-kawa 7 is a stiff straw line.

Breeding procedure of Saikai-kawa 24 is outlined in Table 1. The progeny of the cross was grown by bulk planting from F_1 through F_3 generation in a greenhouse to shorten the time for generation cycles. A total of 1600 seeds of F_1 plants, 2800 seeds of F_2 plants and 5000 seeds of F_3 plants were bulk-harvested.

In the fall of 1968, all seeds of the progeny were space-planted and individual selection was made. Ninety-four early heading, lodging resistant plants were selected. In the fall of 1969, the F_5 plants were grown in rows. Eleven superior rows were selected by field observations.

To show the scale of the breeding procedure, a total number of crosses and populations is given as follows:

In 1967, 24 crossings including Saikai-kawa 7/Asahi 5 were made and almost all progenies of the crosses were grown in the greenhouse in 1967/68. In 1968/69, 11 populations were grown for individual selection and a total of 1234 plants were selected. In 1969/70, they were grown in rows and a total of 116 superior rows were selected.

2) Yield test and adaptability test

In 1970/71, the F_6 strains were grown for preliminary yield test. Plants were grown by

* Present address: Upland Farming Research Center, Central Agricultural Experiment Station (Yatabe, Ibaraki, 305 Japan)

Table 1. Breeding procedure of Saikai-kawa 24

Year	Generation	Breeding procedure
1967 spring	Cross	Saikai-kawa 7 × Asahi 5.
1967/68	F_1—F_3	Bulk planting in green house.
1968/69	F_4	Space planting. 94 plants were selected.
1969/70	F_5	Planted in rows. 11 rows were selected.
1970/71	F_6	Preliminary yield test.
1971/72	F_7	Yield test. Space planted and 5 plants were selected (Named Hakei M 23).
1972/73	F_8	Yield test. Five rows were planted and 1 row was selected (5 plants in the row were selected). Same produre was continued at later generations. Adaptability test and disease resistance test*.
1973/74	F_9	Yield test. Adaptability test* and disease resistance test*. (Named Saikai-kawa 24).
1974/	F_{10}—	Yield test. Disease resistance test*. Test to determine recommendable variety by prefectural agricultural experiment stations*.

* Tests by prefectural agricultural experiment stations. Other procedures not bearing asterisk were undertaken by Kyushu National Agricultural Experiment Station (Chikugo).

ridge culture, replicating twice. Plot length was 4 m, and the distance between ridges was 0.7 m. Four out of 11 strains were selected by field observations and harvested Two high yielding strains were selected finally. In addition, 9 strains of other populations were also selected and a total of 11 strains were grown in yield test next year.

In 1971/72, yield test was made by two different cultural methods; ridge culture, and broadcast-rotavating culture, replicating twice respectively. For maintaining purity and multiplication of seeds, seeds were space-planted and 5 plants were selected. One line of the progeny was named Hakei M 23, which was named Sakei-kawa 24 later. In 1972/73, yield test of Hakei M 23 was made. It was grown in 5 rows and 1 row was selected (5 plants in the row were selected). The same procedure was continued hereafter at later generations. At the same time Hakei M 23 was grown at prefectural agricultural experiment stations for adaptability test and disease resistance test. In 1973/74, Hakei M 23 was tested at 4 prefectural stations; 4-20 lines including Hakei M 23 were grown for the adaptability test. Hakei M 23 was judged as superior line and named Saikai-kawa 24. In 1974/75, yield test of Saikai-kawa 24 was made at Chikugo by 3 different cultural methods; ridge culture, broadcast-rotavating culture and drill culture, replicating twice respectively. To determine whether Saikai-kawa 24 can be a candidate of recommendable variety for each prefecture, it was subjected to the test to determine recommendable variety in 22 prefectural stations in 1974/75, in 12 stations in 1975/76, in 3 stations in 1976/77, and in 2 in 1977/78.

3) Results of yield test

Yield tests conducted at F_7–F_9 generations at Chikugo showed that Saikai-kawa 24 headed 11 days and matured 5 days earlier than Daisengourudo (check variety). Grain yield of Saikai-kawa 24 exceeded Daisengourudo by 10% in ridge culture and 4% in broadcast-rotavating culture. Results of adaptability tests conducted by prefectural station at F_8—F_9 revealed that Saikai-kawa 24 headed 6–19 days earlier than Daisengourudo. Grain yield ranged 80–133% that of Daisengourudo. It exceeded Daisengourudo by 8–33% in Kagoshima and 8% in Aichi Prefectural Experiment Sation.

Results of yield tests conducted at F_{10}–F_{13} at Chikugo are shown in Table 2. Check varieties were Kawasaigoku and Daisengourudo. Saikai-kawa 24 headed 6 days and matured 3 days earlier than Kawasaigoku. It was resistant to lodging with culm length of 87 cm. Its grain yield was 88–92% of that of Kawasaigoku. It did not outyield check varieties except Daisengourudo in ridge culture, though it had more spikes per m^2 and lodged to less extent than check varieties.

Table 2. Yield test conducted at Chikugo for Saikai-kawa 24 at F_{10}—F_{13}

Variety name	Heading date	Maturing date	Culm length (cm)	Spike length (cm)	Spikes per m^2	Lodging	1000-kernel weight (g)	Grain weight (kg/a)		
								1	2	3
Saikai-kawa 24	Apr. 2	May 18	87	6.3	659	1	37.2	40.0	43.9	45.9
Daisen-gourudo	Apr. 13	May 24	90	6.9	510	1-2	40.3	39.2(102)	47.1(93)	48.4(95)
Kawasai-goku	Apr. 8	May 21	88	6.8	608	2	36.7	45.4(88)	48.4(91)	49.7(92)

Figures in the table show averages of 4 years tests by ridge culture except grain weight 2 and 3. Grain weight 2 and 3 indicate the grain weight obtained by broadcast-rotavating culture, and drill culture, respectively. Figures in the parenthesis indicate grain yield of Saikai-kawa 24 in percentage to that of check varieties.
Lodging was rated as 0 (no lodging) to 5 (full lodging).

In Table 3, results of the test to determine recommendable variety conducted by prefectural stations are summarized. Though Saikai-kawa 24 is early maturing, its grain yield was lower than local leading varietes, ranging 68–161% of the local leading varieties at F_{10}, and 59–103% at F_{11}. The overall average yield of Saikai-kawa 24 in the tests was 90% of local leading varieties, and judged "poor" in most places. However, disease resistance tests conducted by prefectural and national stations showed that Saikai-kawa 24 is resistant to powdery mildew and moderately resistant to scab, the most severe disease in Kyushu, as given in Table 4.

Table 3. Grain yields of Saikai-kawa 24 shown in the tests to determine recommendable variety conducted by prefectural stations at F_{10}—F_{13}

Prefectural stations	Generation			
	F_{10}	F_{11}	F_{12}	F_{13}
Fukuoka	△ 91—104 (4)	×—△ 94—103 (2)		
Saga	△ 82	× 88		
Nagasaki	△ 97	× 84		
Kumamoto	△ 100	× 75		
Oita	× 79			
Miyazaki	× 75— 98 (3)			
Kagoshima	×—○ 89—117 (2)			
Yamaguchi	×—△ 76—161 (2)	△ 88	× 86	
Hiroshima	△ 78	× 70		
Okayama	× 86			
Shimane	○ 96	△ 59	△ 72	△ 66
Gifu		○ 95	△ 117	○ 118
Shizuoka	△ 68	× 61		
Chiba	○ 130	× 96		
Saitama	× 79			
Ibaraki	× 87			

Grain yield is shown as percentage to that of local leading varieties.
Figures in the parenthesis indicate number of test sites.
Evaluation by prefectural stations: × (poor), △ (less promising) and ○ (promising).

Table 4. Disease resistance test of Saikai-kawa 24 conducted by prefectural and national stations at F_8—F_{13}

Disease	Experiment station	Variety	Generation					
			F_8	F_9	F_{10}	F_{11}	F_{12}	F_{12}
Scab	Kagoshima Pref.	S		R R	M	S—M	M	R
		K		R	S—M	M	S—M	R
		D		R	S—M	S—M	M	M—R
	Kochi Pref.	S				R	S—R	
		K				R	S—M	
	Kyushu Natl.	S				M	S—M	M
		K				S—M	M	M
		D				S—M	M	M
	Tokaikinki Natl.	S	M—R					
		K	M—R					
		D	M—R					
Powdery mildew	Nagasaki Pref.	S	R R	R	R	R	M—R	R
		K	R R	S	S—M	S	S—M	S
		D	R		S	S	S—M	S
Barley yellow mosaic virus	Yamaguchi Pref.	S	S	S	S S	S	S—M	S S
		K	S S	S S	S S	S S	S S	S S
		D	S S	S S	S S	S S	S S	S S
	Ehime Pref.	S	R	R		R	S—R R	M
		K	M	M		R	S—R	M
		D	M	R		R	M—R	R

Rating: SS (highly susceptible), S (susceptible), M (intermediate), R (resistant) and RR (highly resistant)
Variety: S : Saikai-kawa 24, K : Kawasaigoku, and D : Daisengourudo.

BYMV resistant lines

As stated before, 2-rowed barleys are widely grown in Kyushu because of their scab resistance. But almost all 2-rowed barleys grown in Kyushu are susceptible to a virus-like disease[4] caused by barley yellow mosaic virus (BYMV)[3]. (Occurrence of the virus-like disease in Kyushu by BYMV was also identified by Iwasaki, unpublished data). BYMV is transmitted *via* soil and reduces yield significantly[1]. Early maturing and stiff straw lines, Saikai-kawa 29, Saikai-kawa 30 and Saikai-kawa 32 developed at Chikugo are resistant to BYMV. Prefectural stations are now conducting yield tests of them for selecting recommendable variety.

1) Crossing and early generations

Saikai-Kawa 29 and 30 originated from the cross Kawasaigoku//Haganemugi/Asahi 5, and Saikai-kawa 32 from the cross Saikai-kawa 11//Haganemugi/Asahi 5, which were made in 1969. As Kawasaigoku, Asahi 5 and Saikai-kawa 11 are highly susceptible to BYMV (tested by Yamaguchi Prefectural Agricultural Experiment Station, 1969), the BYMV-resistant character might be traced, probably, to Haganemugi, though the screening test of Haganemugi for BYMV has not been conducted.

Saikai-kawa 29 and 30 were derived from single F_3 plants. In 1974/75, the strains of the progeny were grown in preliminary yield test at F_6. Yield tests of them were conducted at F_7–F_{10} in 1975～79 growing seasons at Chikugo. They were grown at 4–5 prefectural stations for adaptability tests at F_8 and tested by 10–15 prefectural stations for selecting recommendable variety at F_9–F_{10}. Breeding procedure of them was nearly the same as those of Saikai-kawa 24. Screening tests for BYMV resistance were not conducted in early generation. The BYMV resistance tests were conducted at F_8–F_{10} in BYMV-infected soil at

Table 5. Yield test conducted at Chikugo for Saikai-kawa 29, 30 and 32

Variety	Heading date	Culm length (cm)	Grain weight (kg/a)	Loding
Saikai-kawa 29	Apr. 3	88	59.1	0.8
Saikai-kawa 30	Apr. 12	83	44.5	0.0
Saikai-kawa 32	Apr. 3	89	51.3	0.2
Daisengourudo	Apr. 12	87	43.6	0.8
Kawasaigoku	Apr. 10	88	44.8	1.6

Figures in the table show averages of 3 years from 1976 to 1979 growing seasons. Plants were grown by ridge culture. Sown in late November. Lodging was scored, 0 (no lodging) to 5 (full lodging).

Yamaguchi Prefectural Agricultural Experiment Station.

2) Yield test and BYMV resistance test

Yield tests of Saikai-kawa 29, 30 and 32 are summarized in Table 5. They headed 7–8 days earlier than Kawasaigoku. Grain yield of Saikai-kawa 29 and 32 exceeded Kawasaigoku by 32 and 15%, respectively. Saikai-kawa 30 lodged to less extent than check varieties. While check varieties were highly susceptible to BYMV, Saikai-kawa 29 and 30 were moderately resistant or resistant and Saikai-kawa 32 was generally resistant (Table 6). Saikai-

Table 6. BYMV resistance test in BYMV infected soil

Variety	Generation			
	F_7	F_8	F_9	F_{10}
Saikai-kawa 29		R	M	R—M
Saikai-kawa 30		R	M	M
Saikai-kawa 32	R R	R R	R—M	R R
Daisengourudo	S S	S S	S S	S—S S
Kawasaigoku	S S	S S	S S	S S

Tests were conducted by Yamaguchi Pref. Agr. Exp. Sta. Rating of resistance: Same as Table 4.

kawa 29 and 32 grown in BYMV-infected farmer's fields (Table 7) were not infected, but check varieties Seijyo 17, Kawasaigoku and Saikai-kawa 25, were infected. Particularly at Katsumoto, Nagasaki, culm length and grain yield of check varieties were reduced markedly due to BYMV. In all sites, BYMV resistant lines outyielded check varieties.

Table 7. Yield test of Saikai-kawa 29 and 32 in BYMV infected farmer's fields

Variety	Degree of infection	Grain weight (kg/a)	Culm length (cm)
(Grown in 1977/78, at Moriyama, Nagasaki)			
Seijyo 17	3–4	39.8	98
Kawasaigoku	4	36.2	90
Saikai-kawa 32	0	41.2	92
(Grown in 1978/79, at Moriyama, Nagasaki)			
Kawasaigoku	3	33.8	83
Saikai-kawa 29	0	42.6	80
Saikai-kawa 32	0	35.1	82
(Grown in 1978/79, at Katsumoto, Nagasaki)			
Kawasaigoku	5	25.2	49
Saikai-kawa 25	4	32.3	52
Saikai-kawa 32	0	35.5	78

Data from Nagasaki Pref. Agr. Exp. Sta. Seisekisho (unpublished data). Degree of infection was graded, 0 (no infection) to 5 (extremely infected).

Discussion

Breeding objective of Saikai-kawa 24 was early maturing, stiff straw, disease resistance and high yield. Breeding procedures of Saikai-kawa 24 were typical of the methods employed at Chikugo. Though Saikai-kawa 24 was extremely early maturing, and resistant to loding and to some diseases, grain yield was rather low, only 90% of check varieties, contrary to the objective set forth at the beginning. Because of this low yield, tests in prefectural stations evaluated this variety as "poor". However, it was found later that this variety gives the best result in the late-summer sowing cultivation[2], although it gives rather low yield in the conventional fall sowing cultivation. Results of the studies on late-summer sowing cultivation of barley are given in the other paper[5].

One of the ancestry of Saikai-kawa 29, 30 and 32 is Haganemugi, which is a 6-rowed barley, most resistant to lodging. Primarily, they were selected for the purpose of developing stiff straw varieties. Therefore, selections

in the early generations were for early maturing and lodging resistance. The BYMV resistance of these varieties was revealed in the BYMV resistance tests conductd at later generations. Saikai-kawa 29 is high yielding, Saikai-kawa 30 is lodging resistant, and Saikai-kawa 32 is most resistant among them. In infected fields they outyielded BYMV susceptible varieties.

The standard breeding procedures for barley at Chikugo are; crossing parents, bulking in early generations in greenhouse, followed by individual plant or head selection, seed-multiplication and further selection by observations and preliminary yield testing. Lines in later generations are tested for yield at Chikugo and, simultaneously tested for adaptability, disease resistance and yield at several prefectural stations. Prefectural stations evaluate, in close cooperation with breeding center, which line can be recommended for the farmer's use based on the tests for determining recommendable varieties conducted by each prefectural station.

In Kyushu, the yield of barley is low and it fluctuates badly from year to year. The main reason is rain damage which occurs during ripening period. Early maturing help evading rainy season in June. We have no good breeding materials for scab resistance, though 2-rowed barleys are generally more resistant to scab than 6-rowed barleys. Early maturing also can reduce the occurrence of the disease. Other diseases in Kyushu are powdery mildew, leaf stripe and BYMV. Developing powdery mildew resistant lines is now underway. Growing barley in paddy field often causes wet injury. Though varietal difference of tolerance to wet injury is amall, researches on the selection methods are also underway.

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