Breeding of a New Malting Barley Cultivar Houshun by the *Bulbosum* Method

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Northern Kyushu is one of the main production areas of malting barley in Japan. Fukuoka Prefecture located in this area had 3,200 ha of malting barley hectareage in 1997. The double cropping system consisting of rice and barley or wheat is mainly employed in this area, and malting barley is the most important crop because of the early maturity. Two leading cultivars for malting barley are Amagi Nijo and Asaka Gold. Amagi Nijo is susceptible to barley yellow mosaic virus (BaYMV) and powdery mildew (caused by *Erysiphe graminis hordei*), and Asaka Gold is susceptible to powdery mildew. Miharuru Gold released in 1995 has good agronomic performance with disease resistance and excellent malting quality, but maturing is slightly later than the above cultivars. Development of the early maturing cultivar with disease resistance, promising agronomic performance and high malting quality is indispensable to promote the malting barley production.

In barley breeding, the production of a barley haploid by interspecific hybridization between *Hordeum vulgare* and *H. bulbosum* was first shown by Kasha and Kao in 1970. Previously, we obtained promising doubled haploid malting barley lines (Furusho and Yoshida 1992) by a highly efficient haploid production procedure (Furusho *et al.* 1990). The objective of this study was to develop an early maturing, high yielding, high malting quality and resistant to BaYMV and powdery mildew two-rowed malting barley cultivar using the haploid production procedure.

Breeding process

Fig. 1 shows the pedigree of Houshun. The haploid breeding with *bulbosum* method as described by Furusho *et al.* (1990) was used instead of the conventional breeding method to develop Houshun. F₁ plants derived from Yoshikei 19/Kanto Nijo 25 were crossed with

Hordeum bulbosum (Cb2920, 2n=2x=14). By the pollination of 674 florets of F₁ with *H. bulbosum*, 482 embryos were obtained and 154 haploid plants regenerated from the embryos cultured. After chromosome doubling by colchicine treatment, 98 doubled haploid lines (DH) were obtained in 1988. By a small plot test for agronomic performance, 65 out of 98 lines were evaluated and 28 lines were selected in 1988/89 (sown in autumn of 1988 and harvested in spring of 1989). In 1989/90 and 1990/91, (one year after obtaining DH), preliminary yield trials and test of malting quality were conducted and 7 lines were selected. One of the 7 lines was selected and tested by a local adaptability test consisting of a yield trial and malting quality analysis at 6 locations for two years (1991/92-1992/93). Since this line showed a good agronomic performance and high malting quality, further yield trials, test of malting quality and local adaptability test were conducted at 12 to 22 locations in a joint malting barley breeding experiment (Sasaki 1990) for four years (1993/94-1996/97). Finally, this line (originally called Kyushu Nijo 12) was adopted by Fukuoka Prefecture as a recommended two-rowed malting barley cultivar in 1998, and was registered as Houshun (two-rowed barley Norin 19) and released in 1999 by the Ministry of

Fig.1. Pedigree of Houshun. The characters in parentheses show the cultivar names registered after crossing.

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Agronomic performance and malting quality

The field data obtained for the performance of Houshun from 1993/94 to 1996/97 in Fukuoka Agricultural Research Center are reported here. Amagi Nijo, a leading cultivar for malting barley in Japan, was used as a standard cultivar. Asaka Gold (Yoshida *et al.* 1991) and Miharu Gold (Yoshikawa *et al.* 1997) released from our breeding program were employed as check cultivars. All entries were sown in four-row plots, 5.0 m long with a 0.3-m row spacing, at a planting density of 150 seeds m⁻², arranged in a randomized complete-block design with three replications. Plots were sown by a cone-seeder (Furusho and Yoshida 1990) at the end of November each year. The following data were collected: date of maturity; lengths of culm and spike; number of spikes per square meter; lodging measured on a 0 to 5 scale; percentage of plump grains; plump grain yield and 1000-plump grain weight adjusted to 13% moisture including the grain weight; percentage of occurrence of hull-cracked grains and grains with ventral swelling; and inspection grade judged by the Fukuoka local food agency office.

The test of malting quality was conducted at Tochigi Prefectural Agricultural Experiment Station using the materials harvested at Fukuoka Agricultural Research Center in 1993/94 to 1996/97.

The agronomic performance and malting quality data were subjected to analyses of variance.

Table 1 shows the agronomic performance of Houshun. Houshun showed the earliest maturity among the cultivars tested. No significant differences in culm length and lodging were observed among the cultivars. Spike length was the same as that in Amagi Nijo and Miharu Gold but shorter than that in Asaka Gold. The

number of spikes was higher than that in Asaka Gold and not significantly different from that of the other two cultivars. Houshun had a significantly higher percentage of plump grains than Amagi Nijo. The plump grain yield of Houshun was higher than that of Amagi Nijo and Asaka Gold, although not significantly. The 1000-plump grain weight was significantly higher in Houshun than in Amagi Nijo, but significantly lighter than that of Miharu Gold. The percentage of hull-cracked grains in Houshun was significantly higher than that in Amagi Nijo, and not different from that in the other two cultivars. On the contrary, the percentage of grains with ventral swelling was significantly lower than that in Amagi Nijo and Asaka Gold. The inspection grade of Houshun was 1 grade higher than that of both Amagi Nijo and Asaka Gold and was the same as that of Miharu Gold.

Table 2 shows the malting quality of the cultivars tested. Malt extract and extract yield of Houshun were significantly higher than those of Amagi Nijo and Asaka Gold, but did not differ from those of Miharu Gold. No significant differences were observed among the cultivars for total nitrogen, soluble nitrogen and apparent final attenuation. Kolbach index was significantly higher than that in Asaka Gold, but not different from that in Amagi Nijo and Miharu Gold. The diastatic power in Houshun was higher than that of Amagi Nijo and Asaka Gold, although not significantly. The quality index, which shows the degree of total malting quality, was significantly higher in Houshun than in Amagi Nijo and Asaka Gold and not different from that of Miharu Gold.

Resistances to BaYMV and powdery mildew

The response to barley yellow mosaic virus at the field infested with BaYMV (virus strain type I) was recorded to clarify the genetic background. Five F₁ populations

Table 1. Agronomic performance of Houshun (Means of 1993/94–1996/97)

Cultivar	Maturing Date	Length		No. of spikes / m ²	Lod- ging ¹⁾	Plump grain ²⁾	Plump grain yield ³⁾	1000- plump grain weight	Hull- cracked grains	Grains with ventral swelling	Inspection grade ⁵⁾
		Culm	Spike								
		(cm)									
Houshun	May 24a ⁶⁾	93.8a	6.3ab	556b	0.8a	93.4b	40.2a	45.9b	2.3b	0.6a	5.3
Amagi Nijo	May 28b	94.3a	6.4b	535ab	1.0a	85.5a	38.0a	43.2a	0.1a	4.2b	6.5
Asaka Gold	May 27b	92.0a	6.8c	497a	0.5a	91.6ab	38.2a	45.0ab	0.7ab	6.8b	6.2
Miharu Gold	May 29b	91.5a	6.0a	531ab	0.4a	92.2ab	41.2a	50.7c	1.1ab	0.1a	5.6

¹⁾ Lodging evaluated by observation on a scale of 0 to 5 (0 = no plants lodged, 5 = completely lodged).

²⁾ Percent seeds over a 2.5 mm slotted sieve.

³⁾ Plump grain yield obtained from grain yield × percentage of plump grains.

⁴⁾ The percentage data of hull-cracked grains and grains with ventral swelling were transformed by arcsine prior to statistical analysis.

⁵⁾ Inspection grade consists of 10 grades of quality; i. e., 1–3: First grade—upper, –middle, –lower, 4–6: Second grade—upper, –middle, –lower, 7–9: Third grade—upper, –middle, –lower, and 10: Out of grade as malting barley.

⁶⁾ Means in a column followed by the same letter are not significantly different at $P \leq 0.05$ based on Tukey's method.

Table 2. Malting quality of Houshun¹⁾ (Means of 1993/94–1996/97)

Cultivar	Malt extract (%)	Extract yield (%)	Nitrogen		Kolbach index (%)	Diastatic power		Apparent final attenuation (%)	Quality index
			total (%)	soluble (%)		(WK)	(WK/TN)		
Houshun	84.0b	76.7b	1.62a	0.77a	47.6b	292a	181a	84.4a	66.7b
Amagi Nijo	81.8a	75.0a	1.62a	0.72a	44.5ab	285a	175a	83.3a	50.4a
Asaka Gold	82.5a	75.6a	1.64a	0.72a	43.9a	249a	153a	85.3a	51.7a
Miharu Gold	83.5b	76.4b	1.73a	0.80a	46.2b	409b	240b	84.7a	71.7b

¹⁾ Malting quality was tested at Tochigi Prefectural Agricultural Experiment Station.

²⁾ Means in a column followed by the same letter are not significantly different at $P \leq 0.05$ based on Tukey's method.

Table 3. Response to BaYMV of F₁ and F₂ plants

Cross combination φ / σ^7	Response to BaYMV ¹⁾			
	F ₁		F ₂	
	R:S ²⁾	R:S	$\chi^2(1:3)$	$\chi^2(7:9)$
Mokusekko 3(<i>ym1</i> , <i>ym5</i>)/ Houshun	10:0	—	—	—
Mihorihadaka 3(<i>Ym2</i>) ³⁾ / Houshun	0:9	—	—	—
Ea52(<i>ym3</i>) / Houshun	0:10	—	—	—
Misato Golden(<i>ym5</i>) / Houshun	10:0	129:0	387.00**	165.86**
New Golden(++) ³⁾ / Houshun	0:10	32:92	0.04 ^{ns}	16.22**

¹⁾ Results obtained from the field infested with BaYMV strain type I. Expected ratios of 1:3 and 7:9 exhibit one gene segregation and two gene segregation, respectively.

²⁾ R = resistant, and S = susceptible.

³⁾ *Ym2* is a partially dominant resistance gene and New Golden is susceptible cultivar.

**, ^{ns}: Significant at 1% and not significant at 5% levels, respectively.

obtained by crossing Houshun with Mokusekko 3, Mihorihadaka 3, Ea52, Misato Golden and New Golden, and two F₂ populations obtained by crossing Houshun with Misato Golden and New Golden were used. Chi Square analysis was used to test the genetic model.

The response to BaYMV in the five F₁ and two F₂ populations are shown in Table 3. There were no symptoms in two F₁ populations, one obtained by crossing Houshun with Mokusekko 3, which has two recessive resistance genes *ym1* and *ym5* (Konishi *et al.* 1997), and one obtained by crossing Houshun with Misato Golden, which has the recessive resistance gene *ym5*. F₁ obtained by crossing Houshun with Mihorihadaka 3, which has a partially dominant resistance gene *Ym2* (Takahashi *et al.* 1973), Ea52, which has a recessive resistance gene *ym3* (Ukai and Yamashita 1980) and a susceptible cultivar New Golden showed a susceptible response. All F₂ plants obtained by crossing Houshun with Misato Golden showed resistance. However, a clear separation of susceptible and resistant

plants was observed in the F₂ plants obtained by crossing Houshun with New Golden. Segregation ratio fit a 1:3 (one recessive resistance gene segregation) resistant : susceptible distribution, but did not fit a 7:9 (two recessive resistance gene segregation) by χ^2 analysis. These results indicate that BaYMV resistance of Houshun is controlled by a single recessive resistance gene and is allelic to *ym5*.

Houshun showed no symptoms in response to powdery mildew, while Amagi Nijo and Asaka Gold were susceptible in this study. Although the resistance gene was unknown, these results indicated that Houshun had resistance gene (s) to powdery mildew.

Houshun is the first two-rowed malting barley cultivar developed by using the *bulbosum* method in Japan. By haploid breeding using *bulbosum* method, the evaluation of agronomic performance and malting quality could be started from the year after obtaining DH. Thus, two years were shortened to develop lines which could be tested in a local adaptability test (Furusho and

Yoshida 1992). Although the years necessary for further tests were the same as with the conventional method, evaluation of the DH lines might be accurate because of their homozygosity.

Houshun has good agronomic performance and high malting quality. The maturing date was the earliest compared with other check cultivars. Houshun we developed and Miharu Gold released in 1995 have high yielding, excellent malting quality and disease resistance, and differ only in maturing date. Therefore, these two cultivars may be used effectively for malting barley production instead of Amagi Nijo and Asaka Gold.

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