Chapter 35
Recent Improvements in Japanese Wheat Varieties

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Abstract In Japan, the breeding of new wheat varieties for use in bread, Chinese noodles, as well as other noodles, is an urgently required objective if domestic wheat production and food self-sufficiency ratio have to increase. Many molecular markers are now available; those used in wheat breeding programs in Japan are generally to assess the amylose content, dough strength, grain hardness, wheat yellow mosaic virus, preharvest sprouting, and *Fusarium* head blight. Hard and extra-strong wheat varieties have been released using marker-assisted selection.

Background: Domestic Wheat in Japan

Figure 35.1 shows the trends in wheat production area and yield in Japan after World War II. The disorder in the immediate aftermath of the war resulted in a sharp decrease in the production area, which recovered to a maximum level in 1949. However, from 1949 until about 1975, the production area decreased to less than 100,000 ha, in particular with a sharp decrease from 1963. After 1975, the production area began to gradually increase, peaking by around 1988, before decreasing until 1994. Recently, the production area has stabilized at approximately 200,000 ha. Rice production is the main influence on these trends in wheat production area.

Rice is the staple food in Japan. Therefore, following World War II, the Japanese Government boosted rice production. As a result, the area covered by wheat production decreased. However, in about 1970, farmers produced too much rice, and the Government consequently introduced a rice production adjustment in 1970. This adjustment contained two policies: the first was non-cropping, and the second was to changing some rice production area to cultivation of other crops. The second policy led to many farmers beginning to cultivate wheat instead of rice, which led to increase in wheat production.

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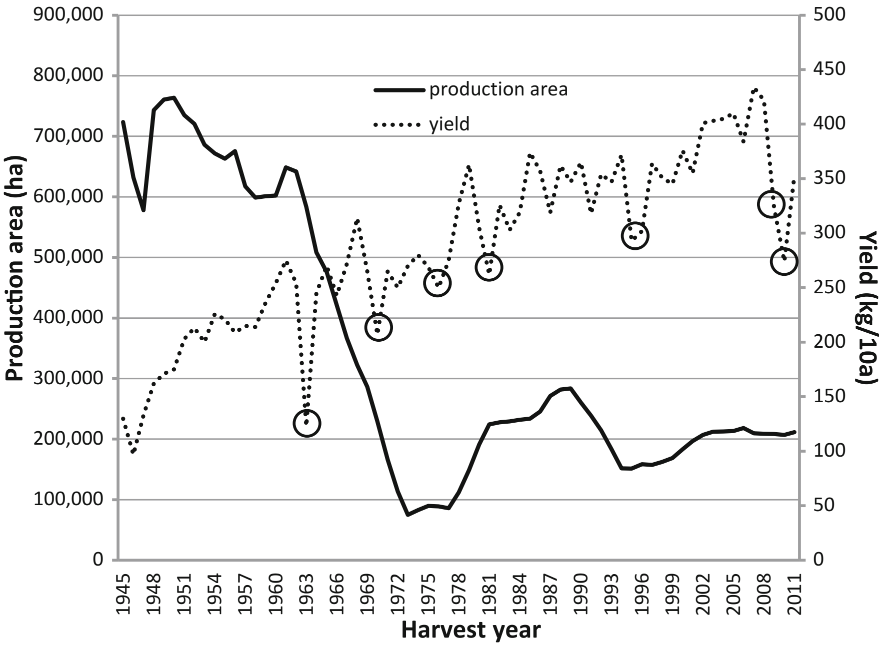


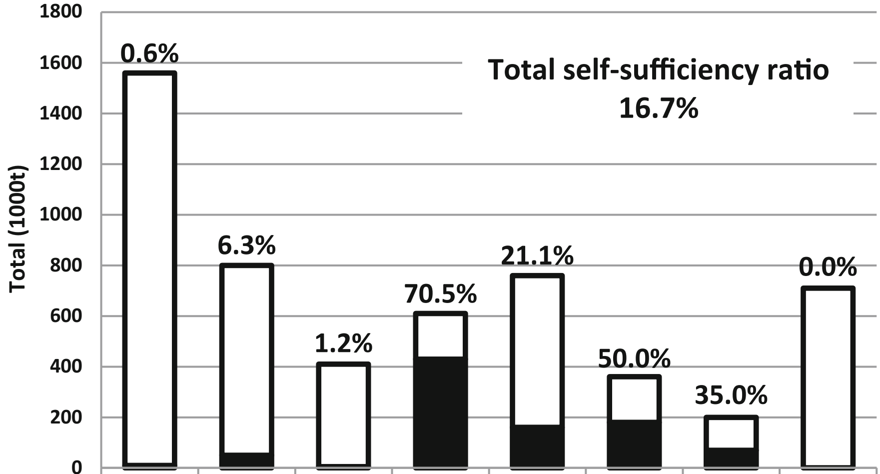
Fig. 35.1 Production area and yield of Japanese wheat

Despite the gradual increase in production after the end of World War II (Fig. 35.1), we can see occasional sharp drops in yield (circles in Fig. 35.1); the drop in 1963 was one of the triggers for a sharp decrease in production area. Yield is unstable, primarily because of degradation in crop quality because of humid and wet weather conditions during the harvest season, specifically causing preharvest sprouting and *Fusarium* head blight damage.

Various products are made from wheat flour in Japan. Chinese noodles are more yellow and elastic than Japanese noodles because the dough is kneaded with kansui, a sodium-carbonate-infused alkaline mineral water, rather than plain water. Instant noodles are also produced. These are dried or precooked and often sold with packets of flavoring, including seasoning oil. Wheat flour is also used in domestic cooking. Each product has a different self-sufficiency ratio (Fig. 35.2). Domestic wheat is mainly used for Japanese noodles, the self-sufficiency ratio of which is already 70.5 %. In contrast, the self-sufficiency ratio of bread, and Chinese and other noodles, is very low.

Wheat Breeding in Japan

Wheat breeding stations are classified into three types in Japan. The first is the National Agriculture and Food Research Organization (NARO) (Fig. 35.3), which manages five wheat breeding stations. NARO was originally a national institute, prior to the privatization of national agricultural institutes in 2001. The second comprises Prefectural Research Institutes, and the third is the Institute of Agricultural



	Bread	Other noodles	Chinese noodle	Japanese noodle	Snack	miso & soy souce	house hold	animal feed
Imported	1550	750	405	180	600	180	130	710
domestic	10	50	5	430	160	180	70	0

Fig. 35.2 Self-sufficiency ratio for Japanese wheat

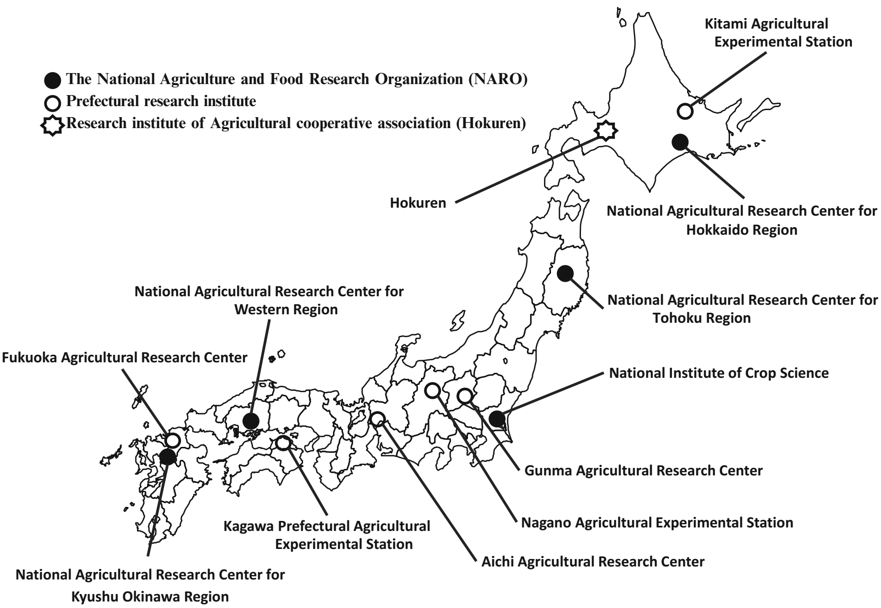


Fig. 35.3 Wheat breeding stations in Japan

Cooperative Associations. No private seed companies in Japan are operating a wheat breeding program; most of the wheat breeding stations are public institutes. Therefore, breeding objectives are always influenced by Government policy.

Every 5 years, the Ministry of Agriculture, Forestry and Fisheries sets the provisions contained in the Basic Law on Food, Agriculture and Rural Areas. These provisions determine the policy basis for food and agriculture. The most recent version, which was approved on May 30, 2010, for the first time set a target for the food self-sufficiency ratio; the target is to achieve a ratio of 50 % in 2020 (40 % in 2008). In order to achieve this, the Government drew up a new policy plan in which domestic wheat production is set to increase from 880,000 t in 2008 to 1,800,000 t in 2020. Current wheat breeding objectives have been established to enable this target food self-sufficiency ratio to be achieved.

To increase domestic wheat production from 880,000 to 1,800,000 t, there needs to be an increased use of domestically grown wheat in wheat products with a currently low self-sufficiency ratio. The target products are bread, Chinese noodles, and other noodles, which are made from hard wheat flour (Fig. 35.2); therefore, breeding of hard wheat is an urgent objective. Hard wheat was not a breeding objective prior to 1999 because domestic wheat was mainly used in the production of Japanese noodles, which are made from soft wheat flour. Hard wheat breeding is however now a higher priority than soft wheat. The required quality standard is equivalent to the Hard Red Winter (HRW) class. However, soft wheat cultivars are still in demand for making Japanese noodles (Udon). The required quality is equivalent to the Australian Standard White (ASW) class; currently, domestic wheat flour yield and color is inferior to ASW.

The wheat harvest coincides with the start of the rainy season, other than in Hokkaido (Fig. 35.4). This means there is always a risk that domestic wheat will be

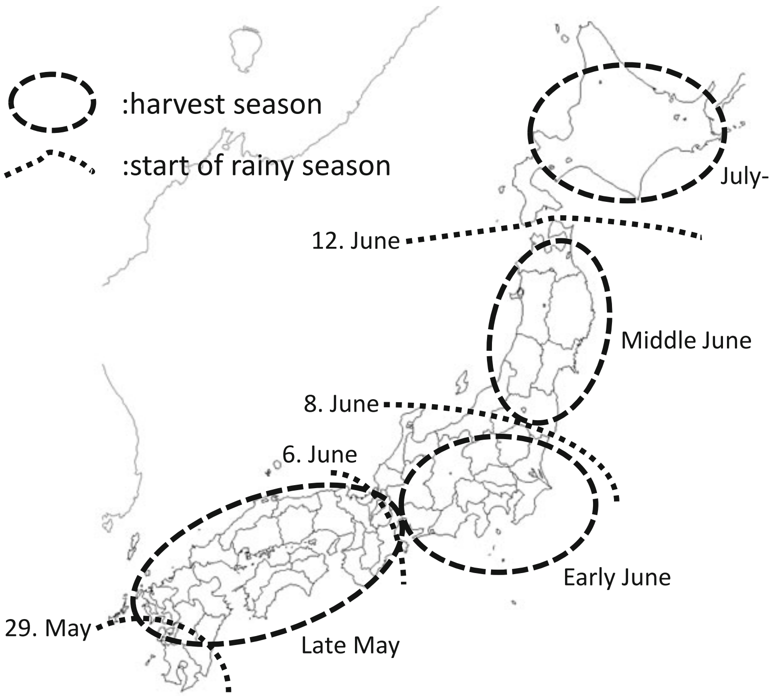


Fig. 35.4 Wheat harvest and rainy seasons in Japan

exposed to conditions of high humidity and wet weather during the harvest season in Japan. Resistance to preharvest sprouting and *Fusarium* head blight resistance are required for both hard and soft wheat.

Marker-Assisted Selection of Wheat Breeding in Japan

Varieties of wheat produced outside of Japan are much better suited to producing good quality bread, whereas domestic wheat is produced to be suitable for making Japanese noodles. In contrast, domestic varieties are superior in terms of agricultural performance (excluding yield, early maturity), *Fusarium* head blight resistance, and preharvest spouting resistance, as they are well adapted to Japanese climate conditions. Overseas varieties provide a useful genetic resource for improving the quality of domestic wheat for bread making. However, it is difficult to breed good quality wheat for bread making that also has high yield and resistance to both *Fusarium* head blight and preharvest sprouting from a single cross. Therefore, the backcross method is considered more reliable in improving domestic wheat quality for bread making.

'Setokirara' was released in 2013, having been bred using the backcross method and marker-assisted selection (Fig. 35.5). 'Fukuhonoka' was chosen as the recurrent parent. 'Fukuhonoka' is a soft wheat cultivar for Japanese noodles, and is well adapted to the temperate climate conditions in Japan. It has a high yield, good preharvest sprouting resistance, and acceptable *Fusarium* head blight resistance. To improve its bread quality, a triple homozygous genotype (*Glu-D1d*, *Glu-B3h*, and *Pinb-D1c*) was selected using a Polymerase Chain Reaction (PCR) marker. 'Setokirara' showed agricultural performance similar to that by 'Fukuhonoka' and quality of the same standard as that by HRW for bread making.

A combination of glutenin subunits *Glu-D1a* and *Glu-B3g* results in extra-strong flour (Maruyama-Funatsuki et al. 2004; Tabiki et al. 2006). 'Yumechikara' is an extra-strong Hard Red Winter wheat cultivar released in 2009 with a marker-assisted selection of these two subunits (Tabiki et al. 2011). Extra-strong flour has a unique bread-making quality. The bread-making quality score for 'Yumechikara' flour was superior to Canadian western No. 1 (1CW) when blended with domestic soft wheat flour (Fig. 35.6).

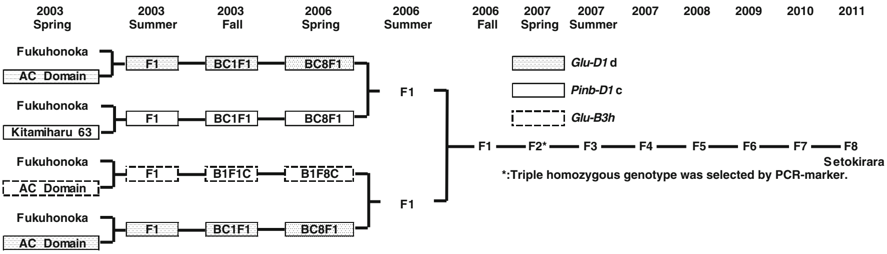


Fig. 35.5 Breeding of 'Setokirara' with good bread-making quality

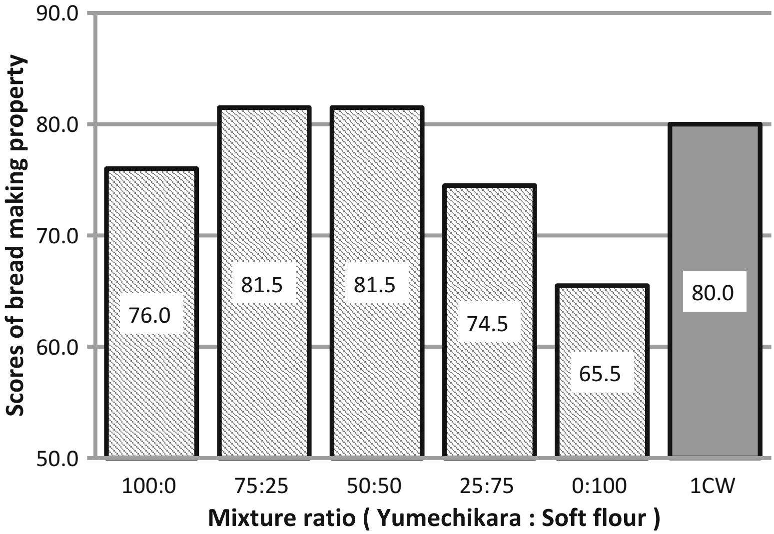


Fig. 35.6 Bread-making quality of 'Yumechikara' blended with soft flour

Wheat yellow mosaic virus is a soil borne disease; outbreaks have been reported on the mainland since 1936, and in 1991, an outbreak was reported in Hokkaido, where half the quantity of domestic wheat is produced. There are many genetic varieties resistant to this disease; for example, 'Yumechikara' is highly resistant. In 2010, a gene, *YmIb*, located on the long arm of the 2D chromosome, was reported as conferring resistance to wheat yellow mosaic virus (Nishio et al. 2010). Markers for this gene were also reported, making it particularly useful, and a backcross program to breed resistant varieties is now in progress.

Preharvest sprouting (PHS) resistance is required for Japanese cultivars. In Japan, breeders use 'Zenkouzikomugi' as a genetic resource for PHS resistance. 'Zenkouzikomugi' has two quantitative trait loci (QTLs) for PHS resistance located on chromosomes 3A and 5A. One of these QTLs was assumed to be the *Mother of FT and TFL1* (*MFT*) (Nakamura et al. 2011). Mapping analysis showed that *MFT* is colocated on chromosome 3A with the PHS-resistant QTL (*Qphs.ocs-3A.1*). Precocious germination of isolated immature embryos was suppressed by transient introduction of *MFT* driven by the maize ubiquitin promoter. This and further evidence showed that *MFT* is a germination repressor and may be the causal gene for *Qphs.ocs-3A.1*. A comparison of the genomic sequences of *MFT-3A* from Chinese spring (which is less PHS-resistant) and 'Zenkouzikomugi' (highly PHS-resistant) revealed single nucleotide polymorphism (SNP). A cleaved amplified polymorphic sequence (CAPS) marker was developed in this SNP.

The Zenkouzikomugi-type allele, which is highly PHS-resistant, is very popular in domestic wheat varieties. In contrast, the Zenkouzikomugi-type allele is very rare in foreign varieties, and the less resistant Chinese spring-type allele is more common. When only domestic varieties were used as cross parents to breed soft wheat for Japanese noodles, this *MFT* CAPS marker was useless because there was no polymorphism. However, when varieties from overseas were used to improve bread-making quality, the *MFT* CAPS marker revealed its usefulness, and it has now started to be used alongside other markers (e.g., *Glu-1*, *Glu-3*, *Gli-1*, *Pina-1*, and *Pinb-1*). In the near future, a new variety will be released with the *MFT* CAPS marker.

There are three types of *Fusarium* head blight (FHB) resistance in wheat.

Type 1: Resistance to FHB initial infection
Type 2: Resistance to FHB spread within the spike derived from the initial infection
Type 3: Decomposition or lack of accumulation of mycotoxins of FHB

In 2011, ‘Wheat Norin PL-9’ was bred from a cross between ‘U24’ (cleistogamous [closed flowering]) and ‘Saikai 165’ (chasmogamous [open flowering]) (Kubo et al. 2012). ‘U24’ is a cleistogamous line with type 1 FHB resistance (Kubo et al. 2010, 2013). However, its agricultural performance is poor (late maturity, long culm length). ‘Saikai 165’ is a derivative of ‘Sumai 3’, which is globally the most popular FHB-resistant genetic resource. ‘Saikai 165’ and ‘Sumai 3’ have a QTL (*Fhb1*) for type 2 FHB-resistance located on the short arms of chromosome 3B. ‘Wheat Norin PL-9’ has a cleistogamous characteristic that increases its resistance to initial infection by FHB; it also incorporates a Saikai 165 (resistant) genotype in *Fhb1*, which was selected by a PCR-marker. It showed similar levels of resistance to the spread of FHB and mycotoxin accumulation as ‘Saikai 165’, and a better agricultural performance than ‘U24’. However, we still need to see an improvement in agricultural performance before releasing a new variety with both type 1- and type 2-resistance to FHB.

Table 35.1 shows the molecular markers used in wheat breeding in Japan. Molecular markers for flour color and yield will be developed in the next few years. Grain yield is an important character for increasing domestic wheat production. However, much further research is needed in order to elucidate the mechanisms driving high yield under Japanese climate conditions before a molecular marker can be developed.

Table 35.1 Use of molecular markers in wheat breeding in Japan

Trait	Marker	Status of application
Amylose content (stickiness, shelf life)	*Waxy*	In current application
Dough strength	*Glu-1*, *Glu-3*, *Gli-1*	In current application
Grain hardness (damaged starch)	*Pina-1*, *Pinb-1*	In current application
Wheat yellow mosaic virus	*YmIb*	In current application
Preharvest sprouting	*MFT* (*Mother of FT and TFL1*)	In current application
Fusarium head blight	*Fhb1*	In current application
Flowering	*Vrn*, *Ppd*	In validation
Flour color	Unknown	Basic research/development
Flour yield	Unknown	Basic research/development
Grain yield	Unknown	Not yet

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