

Identification of the early heading date gene in the Japanese rice cultivar Koshihikari

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We isolated *Hd16* gene which is involved in controlling heading date in rice. The *Hd16* gene encodes a casein kinase-I protein, and is associated with photoperiod sensitivity. We have also shown that a natural mutation within *Hd16* caused a decrease in the function of the gene in the japonica cultivar Koshihikari. This Koshihikari-type mutation may have originated from a Japanese landrace Moritawase about a hundred years ago.

Keywords: Koshihikari, flowering time control, early heading date cultivars

Background

Koshihikari has been a top cultivar in Japan since 1978 because of its superior eating quality and relatively early heading date as compared to other Japanese rice cultivars. Early heading phenotype plays an important role in expanding the range of cultivation particularly in the northern parts of Japan such as Hokuriku and South Tohoku regions where seed maturation must occur within a period of optimal climatic conditions. However, the gene responsible for early heading date has not been characterized so far. Using the reference genome sequence of the *japonica* cultivar Nipponbare as well as the genome sequence of Koshihikari, we were able to identify and subsequently isolate the gene associated with early heading date in rice.

Results and Discussion

1. The heading date of Koshihikari is about 10 days earlier than Nipponbare (Fig. 1). The difference in heading date between these two Japanese cultivars is mainly attributed to the *Hd16* gene.
2. Comparison of the Nipponbare and Koshihikari genomic sequences revealed the existence of a single non-synonymous substitution within the *Hd16* gene encoding a casein kinase-I protein.
3. Biochemical analysis also revealed that the Nipponbare-type *Hd16* recombinant protein is a strongly phosphorylated Ghd7 which regulates the flowering time in rice by changing the photoperiod sensitivity (Fig. 2). On the other hand, the Koshihikari-type *Hd16* recombinant protein is a non-phosphorylated Ghd7 protein with significantly decreased kinase activity.
4. The Koshihikari *Hd16* allele was found in Japanese cultivars but not in any of the wild rices as well as non-Japanese cultivars (Fig. 3). Based on the pedigree of the Japanese rice cultivars, it is likely that the Koshihikari *Hd16* allele may have originated from a Japanese landrace Moritawase (Fig. 4).

Future prospects

1. The *Hd16* gene will accelerate the development of new rice cultivars with desirable heading date and maturation period particularly cultivars that could avoid injury due to high-temperature during the grain filling period and cool temperature at the booting stage.
2. The *Hd16* gene controls photoperiod sensitivity together with other genes such as *Ghd7*. Further analysis is necessary to elucidate the entire molecular genetic pathway for heading date regulation in rice.



Fig. 1. Heading date of the *japonica* cultivars Nipponbare (left) and Koshihikari (right).

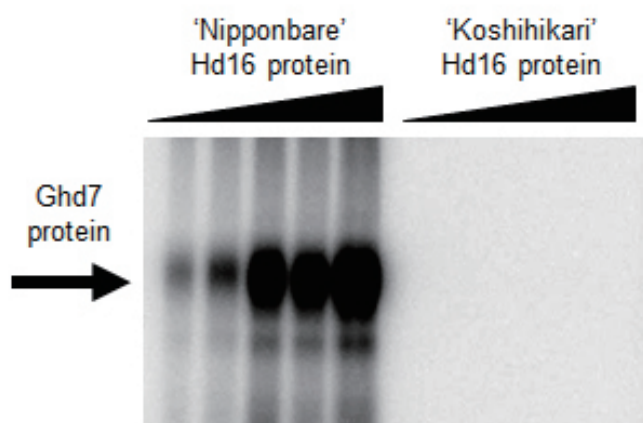


Fig. 2. Phosphorylation assay of Hd16 recombinant proteins. The Ghd7 protein was strongly phosphorylated by the Nipponbare-type Hd16 protein (left) but not by the Koshihikari-type Hd16 protein (right).

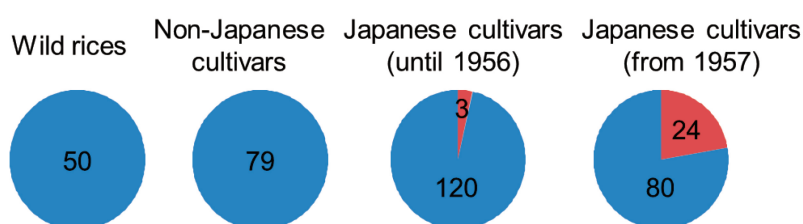


Fig. 3. Distribution of Nipponbare and Koshihikari *Hd16* alleles in cultivated and wild rices. The Nipponbare and Koshihikari allele is indicated in blue and red, respectively. The ratio of Koshihikari allele increased among the Japanese rice cultivars after the release of cultivar Koshihikari in 1956.

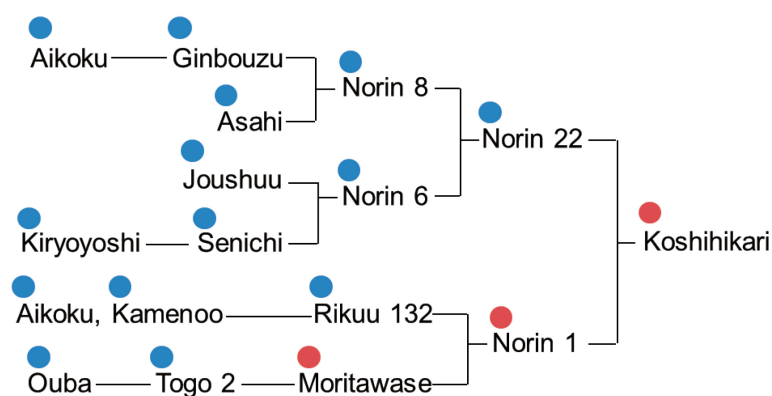


Fig. 4. Origin of *Hd16* gene types based on the pedigree of Koshihikari. The Koshihikari *Hd16* allele may have originated from Moritawase, a Japanese landrace artificially selected about a hundred years ago.

References

1. Hori K, Ogiso-Tanaka E, Matsubara K, Yamanouchi U, Ebana K, Yano M (2013) *Hd16*, a gene for casein kinase I, is involved in the control of rice flowering time by modulating the day-length response *The Plant Journal* 76(1):36-46
2. Patent application #JP-2010-252645 (Japan)