Enlargement of grain size improves nitrogen utilization efficiency in rice

The Green Revolution made it possible to increase crop yields through the application of large amounts of nitrogen (N) fertilizers, but it also resulted in serious environmental pollution. In addition, such production systems are vulnerable to high N fertilizer prices. Therefore, toward sustainable production and supply of rice, increasing the crop grain yield must be achieved without such a considerable input of N fertilization. Our previous studies demonstrated that a large-grain *japonica* rice cultivar, Akita 63, has high nitrogen utilization efficiency per unit of absorbed nitrogen (PNUE) and a large-grain allele of the *GS3* gene. To examine the positive effect of the large-grain allele of *GS3* on rice yields, PNUE, and nitrogen utilization efficiency per unit of fed nitrogen fertilizer (NUE), a near-isogenic line of the large-grain allele of *GS3* originated from Akita 63 was developed in the genetic background of a *japonica* cultivar, Notohikari, with a large grain (LG-Notohikari).

LG-Notohikari always showed longer and wider grains compared to Notohikari in any fertilizer conditions (Fig. 1). Significant grain yield increases for LG-Notohikari were observed in two fertilized plots, with application rates equal to 4.8 and 9.6 g N/m^2, but not observed in the unfertilized plot (Table 1). Among yield components, thousand-grain weight showed significant increases in all conditions tested. Also, grain yield of the LG-Notohikari grown in the 4.8 g N/m^2 plot was similar to that of the Notohikari grown in the 9.6 g N/m^2 plot. NUEs of the LG-Notohikari were significantly higher than those of the Notohikari in both N applications (Fig. 2). Likewise, PNUE of the LG-Notohikari was higher than that of the Notohikari (Fig. 3).

Enlargement of grain size using the large allele of *GS3* improves nitrogen utilization efficiency in rice and can be used in a rice breeding program for reduced amounts of N fertilizer. It should be noted that the effect of improving NUE and grain quality by the enlargement of grain size depends on original varieties, growth conditions, environments, and other factors.

(M. Obara,
Yoon D.K. [Graduate School of Agricultural Science, Tohoku University],
K. Ishiyama [Graduate School of Agricultural Science, Tohoku University],
A. Makino [Graduate School of Agricultural Science, Tohoku University])

Fig. 1. Typical phenotypes of Notohikari and LG-Notohikari grains
Ten grains each of the Notohikari and LG-Notohikari were prepared, and plants were grown in a field in Aobayama, Miyagi, Japan, without N fertilizer application. The scale bar

Table 1. Grain yield and yield components of Notohikari and LG-Notohikari grown with different amounts of N fertilizer

N fertilization	Line	Paddy yield	Total spikelet	Seed fertility	1,000-grain
0	Notohikari	269±4 a	15.0±0.2 a	76.2±1.4 a	24.6±0.5 a
	LG-Notohikari	287±9 a	15.0±0.2 a	74.4±1.8 a	31.0±1.5 b
4.8	Notohikari	338±17 a	21.0±0.6 a	80.3±1.4 a	25.6±0.4 a
	LG-Notohikari	456±26 b	22.0±0.8 a	79.8±1.1 a	29.3±0.6 b
9.6	Notohikari	450±31 a	30.1±0.8 a	76.7±1.4 a	23.1±0.6 a
	LG-Notohikari	535±21 b	28.3±0.8 a	81.8±1.9 a	28.6±0.5 b

Plants were grown at a JIRCAS paddy field in Tsukuba, Ibaraki, Japan. The mean values and standard errors are indicated. Different letters indicate significant differences (P value less than 0.05) between Notohikari and LG-Notohikari in each condition (n=10).

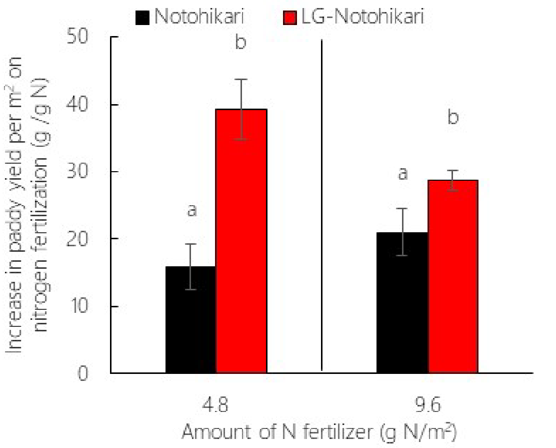

Fig. 2. NUEs of the Notohikari and LG-Notohikari
Plants were grown at a JIRCAS paddy field in Tsukuba, Ibaraki, Japan. The mean values and standard errors are indicated. Different letters indicate significant differences (P value less than 0.05) between Notohikari and LG-Notohikari in each condition (n=10).

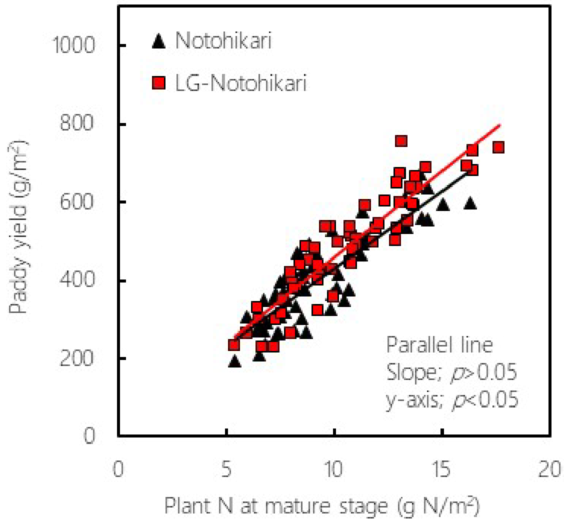

Fig. 3. PNUEs of the Notohikari and LG-Notohikari
Relationship between plant N at mature stage and paddy yield of plants grown at a Kawatabi paddy field in Osaki, Miyagi, Japan

Reference: Yoon et al. (2022) *Plant Direct* 6(7): e417. https://doi.org/10.1002/pld3.417