Identification of a gene involved in leaf photosynthesis rate in high yielding rice variety

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We identified a gene involved in leaf photosynthesis rate from Japanese high yielding rice variety. The gene is associated with modifications in leaf anatomical structure, increase in the number of photosynthetic mesophyll cells, and enhancement of the rate of photosynthesis.

Keywords: genomics assisted breeding, photosynthesis rate, quantitative trait, mesophyll cell

Background

Crop yield is divided into two major conceptual components, namely, source strength corresponding to the ability to produce sucrose via photosynthesis, and sink size representing the size and number of organs for carbohydrate storage. These two components must be increased in a balanced manner to improve the yield. Although recent progress in rice genomics has identified several genes for sink size have been identified by recent progress of rice genomics, there has been less progress toward isolation of genes for involved in traits associated to source strength. A Japanese rice cultivar, Takanari, expresses high level of both source capacity and sink size. In this study, we identified a quantitative trait locus controlling leaf photosynthesis rate in Takanari with and characterized its functional mechanism.

Results and Discussion

1. The gene involved in leaf photosynthesis rate (GPS) was identified by map-based cloning using a population derived from a cross between Takanari and Koshihikari, a representative Japanese cultivar.
2. The locus of GPS is identical with NAL1, a previously reported gene involved in leaf width. The cultivars Takanari and Koshihikari showed several nucleotide polymorphisms in NAL1. Analysis of NAL1 expression levels and anatomical observation of leaf cross-section revealed that the GPS allele of Takanari is a partial loss-of-function type of NAL1.
3. Evaluation of NIL with GPS region of Takanari in Koshihikari genetic background (Koshihikari GPS) and NIL with GPS region of Koshihikari in Takanari genetic background (Takanari GPS) (Fig. 1A) revealed that the GPS allele of Takanari is directly involved in increasing the rate of photosynthesis in the leaf (Fig. 1B).
4. Koshihikari GPS shows relatively thicker leaf and higher number of mesophyll cells per unit area in contrast to Takanari GPS. This trend suggests that the increase in mesophyll cell number is a main factor for enhancing leaf photosynthesis rate.
5. The yield of Takanari GPS is 5% lower than Takanari suggesting that GPS contributes to increase in yield of Takanari. On the other hand, the yield of Koshihikari GPS is the same as Koshihikari.
6. Nucleotide sequences of GPS on the pedigree of high yielding rice indicated that GPS allele of Takanari is derived from indica varieties, Peta or Mudgo, and inherited via IR8, the high-yielding rice variety that propelled the ‘green revolution’ in the 1960’s (Fig. 2).

Future prospects

1. The GPS gene contributes to high source potential and high yield in Takanari and is therefore applicable in marker assisted selection for breeding high yielding rice cultivars.
2. Although Koshihikari GPS did not show improvement in yield performance, it is expected that in combination with other genes such as sink size which has been identified before, it can be used for
yield improvement among Japanese rice cultivars.

3. The GPS gene could be used in basic research particularly in clarifying the mechanisms of photosynthesis.

Fig. 1. Relationship between GPS region and photosynthesis rate. (A) We developed NILs with the GPS region of Takanari in Koshihikari genetic background (Koshihikari GPS) and the GPS region of Koshihikari in Takanari genetic background (Takanari GPS). (B) Evaluation of both NILs revealed that the GPS allele of Takanari increases leaf photosynthesis rate. “a” and “b” indicate statistically significant difference.

Fig. 2. Breeding pedigree of cultivar Takanari and inheritance of the GPS allele. The GPS allele that induces high photosynthesis rate in Takanari is derived from IR8, a high yielding variety that has contributed to the ‘green revolution’ in Southeast Asia in the 1960’s.

Reference