Identification of a quantitative locus, *qPA1*, derived from a black rice variety in Laos, which increases phytic acid content in grains

Upland rice is mainly cultivated in the mountainous regions of northern Laos, where soil fertility is low and average yields remain around 2.0 t ha^{-1}. Black rice has traditionally been grown in this region and is an important crop supporting local diets due to its nutritional value and health benefits. However, poor growth under low-fertility conditions remains a major constraint to stable production. Approximately 60–90% of the phosphorus in grains exists as phytic acid (PA), which is sometimes considered to inhibit mineral absorption from a human nutritional perspective. In rice, however, PA serves as the primary phosphorus source during germination and early growth. Particularly under low-phosphorus conditions, PA functions as an important stored form of phosphorus that supports early seedling development. Therefore, PA is a key trait determining crop adaptability, and breeding programs should focus on phosphorus storage traits in grains. The objectives of this study are to identify a quantitative trait locus (QTL) associated with PA content in grains using a genetic population derived from a cross between Kampeng (a black rice variety from Laos) and Non (a stable, high-yielding white rice variety), and to propose a breeding strategy for developing black rice varieties with improved early growth and stable production under low-fertility conditions.

Results indicate that white rice variety Non produces more panicles and thus higher yield potential compared to black rice variety Kampeng (Fig. 1A, B). On the other hand, Kampeng shows higher PA content in grains compared to Non (Fig. 1C). Genetic analysis using an F_2 population derived from a cross between Non and Kampeng identifies a novel QTL, *qPA1*, at the distal end of the short arm of chromosome 1 in both Ishigaki and Vientiane environments, which increases PA content with the Kampeng allele (Fig. 2A). A QTL associated with grain color was detected in *Kala4*, previously reported as a gene controlling the pigmentation of anthocyanins—a health-promoting component—and the Kampeng allele causes grain color to turn black (Fig. 2B). Subsequent studies using F_3 lines derived from the F_2 population confirm that the Kampeng allele enhances PA content by approximately 23% compared to the Non allele (Fig. 3).

Through backcross breeding, the introduction of the Kampeng alleles of *qPA1* and *Kala4* into Non makes it possible to develop a new black rice variety that exhibits high phosphorus supply capacity during germination and early growth, even under low-fertility conditions, while maintaining stable high yield.

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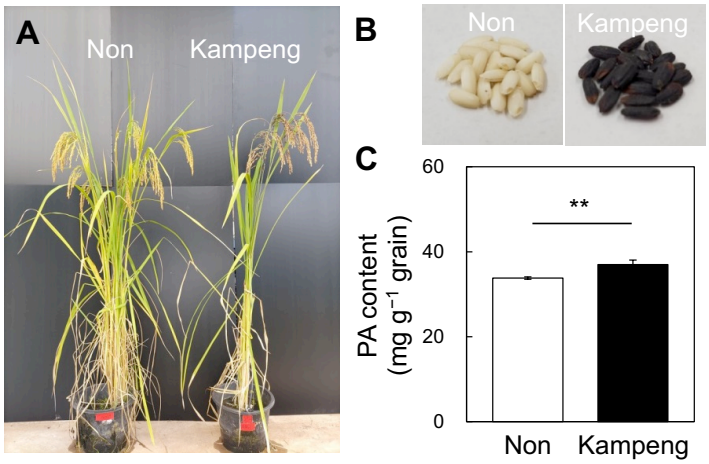

Fig. 1. Phenotype of Non, a stable, high-yielding white rice variety from Laos, and Kampeng, a black rice variety

Plant type (A), grains (B), and PA content in grains (C) of both varieties.
** shows significance at the 1% level by *t*-test.

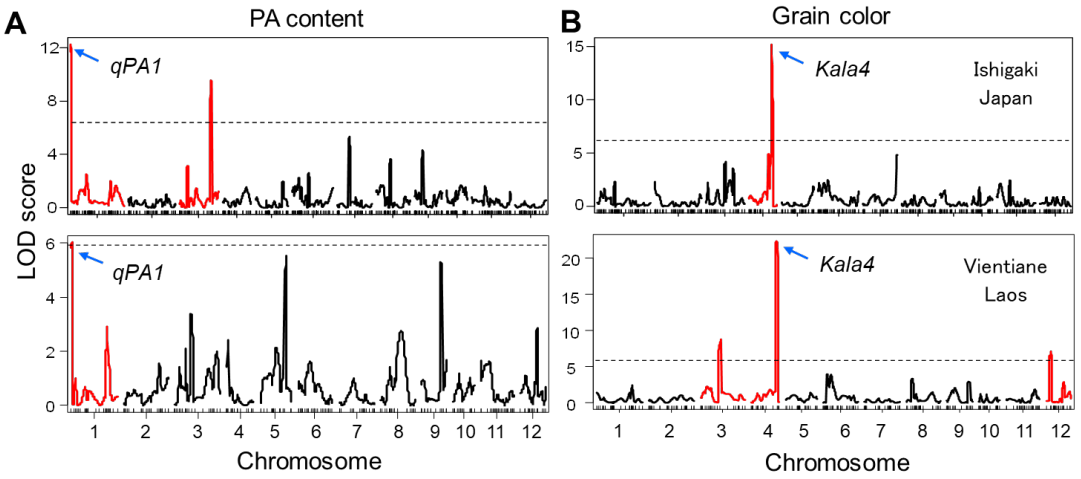

Fig. 2. Genetic analysis of PA content (A) and grain color (B) using an F_2 population derived from a cross between Non and Kampeng

The top and bottom panels show the results in Ishigaki and Vientiane, respectively. The dotted line indicates the threshold for genetic analysis; LOD scores exceeding this threshold are shown in red.

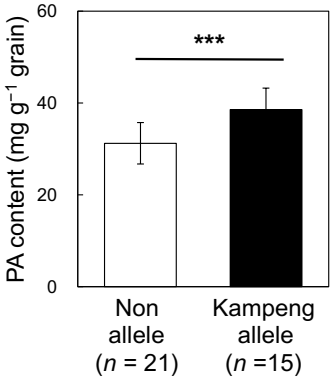

Fig. 3. Comparison of PA content in grains between F_3 lines derived from the F_2 population, where *qPA1* was homozygous for Non and Kampeng, respectively

n indicates the number of lines.
*** shows significance at the 0.1% level by *t*-test.

Reference: Takai et al. (2025) *Frontiers in Sustainable Food Systems* 9: 1620644.