**Agricultural significance of the circadian clock of rice in paddy fields**

Takeshi Izawa, Motohiro Mihara, Meenu Gupta, Hironori Itoh, Ritsuko Motoyama, Atsushi J. Nagano, Masahiro Yano, Yoshiaki Nagamura, Yuji Suzuki, Amane Makino, Yuji Sawada, Masami Yokota Hirai

1Functional Plant Research Unit, NIAS 2Genome Resource Unit, NIAS, 3Argogenomics Research Center, NIAS, 4Tohoku University, 5RIKEN

We first identified a new circadian clock mutant of rice using flowering-time phenotypes. We next grew the mutant in a paddy and extensively analyzed temporal dynamics of transcriptomes, temporal changes of primary and secondary metabolites, photosynthetic performance, and yield-related traits, to elucidate the agricultural significance of the circadian clock of rice in field conditions.

**Keywords:** field environments, rice, transcriptome, metabolome, circadian clock, flowering-time

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**Background**

Extensive evaluations of genetically cloned genes are necessary before they are used for agronomic improvement. Because most evaluations so far have been done in controlled and relatively simple experimental conditions in laboratories, additional tests usually must be conducted in the appropriate target environments. In this study, therefore, we examined a newly isolated mutant affecting the circadian clock of rice growing in paddy fields. We analyzed the temporal transcriptomes, temporal metabolomes (both primary and secondary metabolites), photosynthetic performance, and yield-related traits. As a result, we revealed how the circadian clock contributes to the agronomic establishment of rice.

**Results and Discussion**

1. By screening for revertants of an early flowering mutant of rice (termed se5), which is a photoreceptor-deficient mutation, we identified a new mutant (osgi) and cloned the original gene OsGI (GIGANTEA (OsGI)). We further characterized osgi as the first circadian clock mutant identified in rice. It has been reported that the GI gene, the sole OsGI ortholog in Arabidopsis thaliana, also has a circadian clock function, but the role of OsGI to maintain the circadian clock of rice is more significant than that of GI.
2. We grew the osgi mutant plants in a paddy field in Tsukuba City. Although osgi plants flowered later under short-day conditions than under long-day conditions, flowering of osgi was comparable to the wild-type (WT) cultivar, suggesting the growing conditions in the paddy field mimic the long-day conditions in the laboratory.
3. The photosynthetic rate of osgi is the same as that of WT rice plants.
4. osgi plants had increased sugar content in leaves, increased grain numbers per panicle and panicle numbers per plant, but did not have increased yield due to the smaller grain size of osgi.
5. We performed field transcriptome analysis at 2-hr intervals over 24 hr for four developmental stages and monitored temporal expression patterns for 27,201 genes (Fig.1). More than half of the genes were affected primarily by the circadian clock and less so by environmental changes. In addition, no critical changes in primary metabolites were observed.
6. A significant reduction in fertility under abnormal transplanting conditions indicated that osgi was more sensitive than WT to the changes of growing conditions (Fig.2).
7. Although the circadian clock of rice is involved in regulation of photosynthesis and crop yields, the osgi circadian clock mutant plants were little affected by the typical paddy field conditions tested. However, osgi was very sensitive to atypical transplanting conditions due to reduced adaptability.

**Future prospects**

1. It may be advantageous to monitor the circadian clock in rice as a means to develop new cultivars with broader cultivation areas and tolerance to fluctuating environments. New methods to monitor the circadian clock will be required in the near future.
2. If we can utilize some mutation to reduce the cost to maintain the circadian rhythms some increase of grain yields will be expected when we grow the rice plant under stably controlled diurnal conditions.
3. Experimental results obtained only in laboratory studies should be augmented with as much field data as possible.

![Fig. 1. Field transcriptome analysis](image)

We calculated the Pearson’s correlation coefficient using all combinations of 2-hr interval microarray data (27,201 genes) and plotted the changes for one-time point data as a line. 13 lines are shown. In the wild-type, clear sine-curve lines are observed primarily as two patterns; day-type and night-type. The changes between transcriptomes were less in osgi than those in the wild-type.

![Fig. 2. Fertility of wild-type and osgi mutant plants](image)

When we transplanted at the normal time in May, a high fertility was observed in osgi mutant. When we transplanted in June, the fertility was more reduced in osgi mutant than in the wild-type. **: 1% significant

**References**