World of Knowledge

Stories about Rice Flooding Tolerance

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Most people probably do not know why in Chinese we called rice as water rice and the paddy as water farm, and why normally rice is grown under partially flooded (irrigated) conditions. Irrigation is laborious and requires adequate water source. However, farmers have been growing rice with this traditional way for thousands of years. An important discovery by the human wisdom is in fact hidden behind the story of this very old rice farming practice.

Approximately 4 billion years ago, the earth atmosphere was mainly filled with carbon dioxide (CO_2) (98%), with trace amount of nitrogen gas (N_2) (1.9%), and with no oxygen gas (O_2). Throughout climate and environmental changes of earth, the concentration of O_2 and N_2 increased, while that of CO_2 decreased, leading to the ratio of CO_2 :N_2:O_2=0.03:79:21 existing today. Nowadays, all higher eukaryotes and many microorganisms use O_2 for oxidation of carbohydrates to generate energy (ATP). The solubility of O_2 is very low in water, with concentration of only 1/33 of that in air. Consequently, the underwater life of eukaryotes has to evolve to adapt O_2 deficiency for survival.

Most terrestrial plants could not grow underwater due to drastic decrease of gas diffusion in water compared with in air, as which limits the entry of CO_2 for photosynthesis and of O_2 for respiration. Thus, plants suffer from sugar and O_2 double deficiencies under flooding conditions.

Rice, corn and wheat constitute the three top major crops worldwide. Although these crops are close relatives, only rice is able to germinate and grow under flooding conditions. Our ancestors observed that wild rice could not only grow dominantly in flooded wetland but also serve as food source thousands years ago. Since then, with accumulated experience and breeding programs, rice has been grown worldwide with irrigation system

aiming at controlling most weeds that are intolerant to flooding. Currently, nearly 80% of the world rice production comes from irrigated areas.

Wild type **CIPK15-deficient rice mutant**

Figure 1. Plant growth is impaired in the CIPK15-deficient rice mutant under floodwater.

In fact, flooding has a negative impact on rice growth, as water restricts aerobic metabolism and energy production in roots, which limits nutrient uptake from soil. Farmers have been conducting repeated cycles of irrigation and drainage of rice paddies. Drainage is particularly important prior to flowering and panicle initiation, as acceleration of root growth for more efficient nutrient uptake under aerated condition during these growth stages could significantly increase grain yield. Consequently, the practice for a balance between plant growth and weed control not only minimizes the competition from weeds for nutrients, space, and light meanwhile but also maximizes the crop yield.

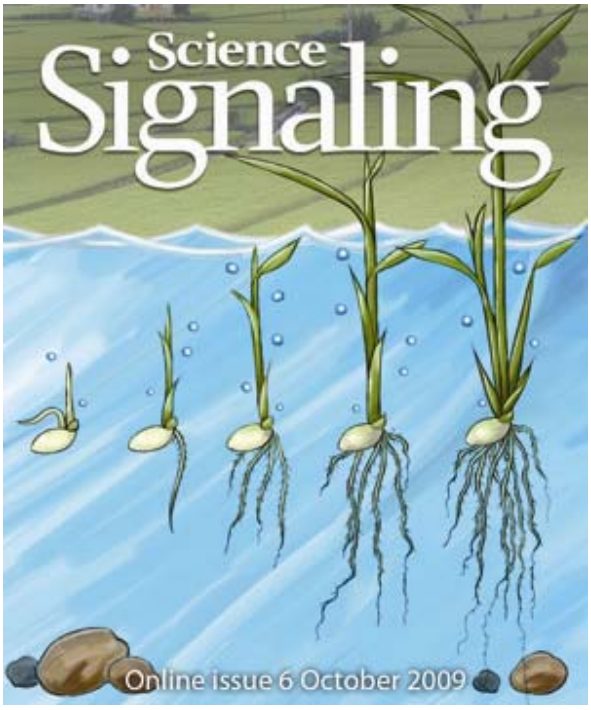

Figure 2. Cover of *Science Signaling* highlights the research on CIPK15 which controls rice flooding tolerance.

Dr. Kuo-Wei Lee in my lab has been leading the research to explore the underlying mechanism that allows rice seeds to germinate and seedlings to survive flooding. He discovered that protein kinase CIPK15 plays

a key role in O_2 deficiency tolerance in rice, by regulating the plant global energy and stress sensor SnRK1A and linking O_2 deficiency signals to the sugar sensing cascade to regulate sugar and energy production, and enables rice growth under floodwater.

Typhoons and flooding have frequently caused tremendous crop loss worldwide. Our discovery of genes and mechanisms enabling rice to germinate and grow under water, not only sheds light on the mystery of rice flooding tolerance known for thousands years but also facilitates breeding of rice and other crops for enhanced flood tolerance.

The image is an artist's rendition of rice seedlings growing under water, quickly establishing themselves to reach the surface of floodwater, and growing in irrigated-lowlands shown in background in 80% of the world's rice production areas. **Artist:** Ms. Annlin Chao, Graduate Institute of Fashion and Communications Design**,** Shih Chien University**,** Taipei, Taiwan, ROC.