RiceCAP facts

USING GENETICS, GENOMICS & BREEDING TO IMPROVE RICE[1]

Peggy G. Lemaux
University of California, Berkeley

Rick Cartwright
University of Arkansas

January 2008

What is RiceCAP?

Coordinated Agricultural Project for Rice

A multi-state, multi-institution project, funded by USDA/CSREES that utilizes new information from genomics to help solve two historically difficult rice problems – milling quality stability and sheath blight disease resistance.

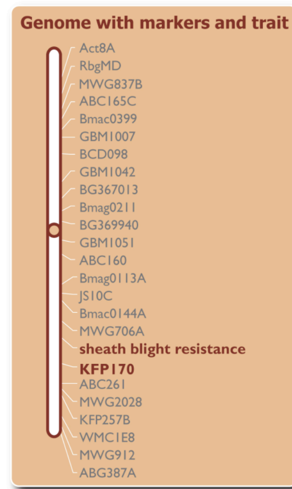
Historically, How Has Breeding Been Used to Improve Rice?

From the early 1940's **classical breeding** involving crossing different varieties has led to substantial improvements in rice. Early successes resulted from the rich genetic resources and extensive breeding expertise available. During the "Green Revolution", breeders introduced semi-dwarfing traits to create shorter, stiff-strawed varieties that increased grain yield. These and other advances resulted in establishment of the U.S. rice industry and reduced imports from traditional rice-producing countries. In later years in the U.S., dramatic yield increases and consistency of annual production resulted from the development of cultivars like 'Labelle' and 'Starbonnet' in the late 60's, grown for over two decades in the South, semi-dwarf medium grain cultivars like 'Calrose 76' and 'M9', other successor cultivars like the popular 'M-202' in California during the 1980s; and semidwarf long grain cultivars in the south during the 80's and 90's, like 'Lemont', 'Cypress' and 'Cocodrie'. Development of 'Gulfmont' in 1986 provided a consistent ratoon crop yield, while the creation of 'Katy' in 1989 was a breakthrough in control of rice blast disease. Production of 'LaGrue' in 1993 in the South resulted in much higher yield in a short stature, long grain rice cultivar. More recently classical breeding has resulted in hybrid rice varieties that set a new standard for yield and are being grown throughout the Southern U.S., Southeast Asia, and Central and South America.

[1] *Information provided by numerous RiceCAP PIs*

What Is Genomics?

Modern plant molecular approaches that use genetics to improve rice have involved studying one or a few genes contained in short fragments of DNA. However, the field of **genomics** investigates the whole genome – with all DNA sequences from the organism. Genomics efforts initially focused on developing a general "road map" of the genome, placing certain markers and traits on a genetic map to aid classical breeding. Later, the entire DNA sequence of certain organisms was deciphered, including indica and japonica rice cultivars.



How Can Genomic Information Be Used in Breeding Efforts to Improve Rice?

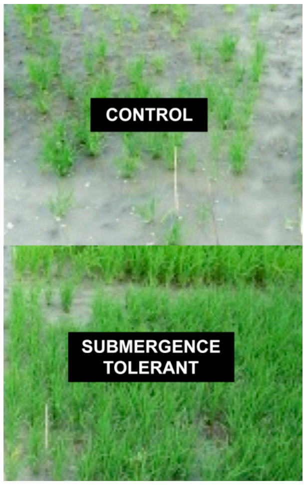
For centuries crop plants were improved by man through selection of the most desirable traits. Today we understand these traits are controlled by heritable DNA sequence differences. By crossing two varieties and following segregation of DNA sequences and traits, it is possible to associate certain sequences in the genome, called markers, with particular traits. Markers can then be used to follow the traits in crosses, a process called **marker assisted selection** or **MAS**. MAS speeds breeding. Also, as genes are found to be responsible for certain traits in rice or other organisms, those genes can be introduced into rice using **genetic engineering** – the manipulation and reintroduction of genes in the laboratory.

Have Any New Rice Varieties Been Developed Using Marker Assisted Selection?

A number of rice varieties have been developed globally and in the U.S. using MAS, which focused on specific traits controlled by single genes that could be introduced quickly into new varieties. For

(continued on reverse)

example, the *Xa21* gene, responsible for **bacterial blight resistance**, was cloned, leading to a nearly foolproof marker within the gene that sped its introduction into other varieties. This gene, plus combinations of other bacterial blight resistance genes like *xa4, xa5, xa7* and *xa13*, was introduced by MAS into commercial rice varieties in China, India, Indonesia and the Philippines. Researchers also identified a region in an indica variety that enables rice to survive **submergence** in water for up to two weeks; it was introgressed into a widely grown Asian cultivar using MAS. Field trials are underway in India and Bangladesh and varieties may be available to farmers in 2009. Several other traits, including resistance to insects, like **brown planthopper**, are being worked on worldwide.



In the U.S. the *Pi-ta* gene, responsible for **blast resistance** in the South, was cloned, leading to identification of "perfect MAS markers" from within the gene; advanced stage blast-resistant lines are in the later stages of evaluation for the U.S. MAS has also been used to develop varieties in the U.S. that are being grown commercially for improved cooking quality. MAS strategies are also being developed for **drought, cold and salt** tolerance, **tungro virus** and **gall midge** resistance, **yield**, enhanced **nutrition**, **seedling vigor** and **grain quality**. **RiceCAP** research is making progress on identifying markers for **milling quality** and **sheath blight resistance** – two difficult traits to select because both are controlled by several genes and are very sensitive to environmental conditions. Having markers for these two traits will be used by breeders to improve crop value and decrease reliance on fungicides.

Have Any New Rice Varieties Been Developed Using Genetic Engineering?

Much genetic engineering (GE) of rice in the U.S. has focused on studying gene function by introducing or knocking out specific genes and observing effects on traits. In 2007 it appears that no GE rice varieties have been commercialized worldwide; however, laboratory and early field evaluations have begun on GE rice varieties that are **blight-resistant**, **stem borer-resistant**, **herbicide-tolerant** and **drought-tolerant**, but most of this work is being done or will be used outside the U.S. Examples include genes for **vitamin A-enhancement** (a.k.a., Golden Rice), which have been bred into a number of varieties at IRRI in the Philippines. Low phytic acid mutants were identified to **increase iron availability**, and also genes were introduced via GE to reduce phytate and increase iron.

In the U.S. rice was engineered to produce **three human proteins**, human serum albumin (HSA), lysozyme and lactoferrin, the latter two were shown to alleviate childhood diarrhea. In October 2006, USDA APHIS issued permits to Ventria Biosciences to grow in Kansas up to 3000 acres of rice expressing lysozyme, 100 acres of rice expressing HAS and 100 acres of varieties expressing lactoferrin (http://www.aphis.usda.gov/brs/aphisdocs/06_27802r_ea.pdf). Although GE varieties might be commercialized in developing countries within 5-10 years, wide-spread production in the U.S. is unlikely in the near future.

What is RiceCAP Doing?

RiceCAP researchers are looking at large, diverse rice populations for traits related to milling quality and sheath blight resistance and trying to identify the specific markers responsible for those traits.