

The hybrid vigour of sexless rice

Researchers mount an ambitious project to create one-line hybrid rice varieties, reports Gio Braidotti

PARTNER COUNTRIES: Global **PROJECTS:** CIM/2002/106: Fertilisation-independent formation of embryo, endosperm and pericarp for apomictic hybrid rice; and CS1/1995/125: Molecular tools for achieving Apomixis in rice **DESCRIPTION:** IRRI and Australian researchers aim to create one-line hybrid rice varieties to help boost rice yields **CONTACT:** Dr John Bennett, j.bennett@cgiar.org



A Cambodian villager harvesting rice: crop yields need to keep pace with population growth.

With more than half the world's population reliant on rice for food security, the International Rice Research Institute (IRRI) in the Philippines is facing a stark challenge in the 21st century. There is a need to ensure crop yields continue to keep pace with population growth at a time of growing scarcity of land suitable for cultivation.

Part of the food security equation is to continue

to apply advanced breeding techniques to lift crop yields. However, the gains needed are daunting. One estimate predicts that by 2030 farmers will need to produce 60 per cent more rice than in 1995.

In recent times, yield improvements have been achieved by harnessing the vigour of first-generation hybrid seed. Chinese scientists bred the world's first rice hybrid in 1974, a significant achievement given that rice normally self-pollinates. The scientists achieved this by transferring the male sterility gene from wild rice to create the 'cytoplasmic genetic male-sterile' or CMS line.

When combined with two other lines, CMS allowed the development of 'three-line hybrid rice', which delivered a 15 to 20 per cent yield increase over high-yielding bred varieties. In 1995, China further refined the technique and developed two-line hybrid rice. The UN Food and Agriculture Organization (FAO) has estimated that with 15 million hectares under hybrid rice cultivation – about half of China's total rice area – national average rice yields increased from 3.5 to 6.2 tonnes a hectare.

However, producing three and two-line hybrid rice seed is technically complex, expensive and out of reach of the poorest growers because of the need to buy seed on a yearly basis to capture the yield benefit, says Dr Abed Chaudhury from CSIRO Plant Industry.

The experts agree that what growers need is a hybrid line whose seed – besides providing a food crop – can produce an embryo that is a clone of the first-generation hybrid plant. Being a clone it can maintain the hybrid vigour of its mother, delivering to the farmer the yield advantage minus the need to buy seed.

The technical name for one-line hybrid rice is apomictic rice. Apomixis is an asexual type of reproduction in which the plant embryo grows from egg cells without being fertilised by pollen. It can be used to lock in hybrid vigour or other desirable agronomic traits because it avoids aspects of the sexual reproduction process, such as meiotic recombination, that lead to genetic variation.

Transforming sexual plant species into apomictic forms is considered the ideal approach by many breeders, and in 1997 Australian researchers and IRRI undertook the mammoth task to make that dream a reality for rice by 2022.

Funded by ACIAR, the project is headed by IRRI's Dr John Bennett and Dr Abed Chaudhury.

"Apomixis is found in some 300 species of plants, including many that are close relatives of cereals, but there is no known relative of rice that is apomictic," Dr Bennett says. "That means the project involves building a synthetic version of apomixis using genetic engineering. If that can be achieved, then there is an outside chance that we can repeat the process through mutagenesis to produce a non-genetically modified (GM) variety."

Dr Bennett explains that normally in rice there are two fertilisation events, both of which need to be modified. One generates the embryo via fertilisation of the egg. The other involves fertilisation of a cell that produces the edible endosperm.

"The CSIRO team has made significant headway solving the problem of endosperm production in the absence of fertilisation," Dr Bennett says.

From work done with *Arabidopsis* (the model plant system for experimental genetics), the CSIRO team was able to identify – for the first time – the genes that control partial apomictic development, the so-called FIS (fertilisation-independent seed) genes.

"Because the FIS genes are present in rice and the rice genome has been sequenced, we could readily isolate FIS-class genes in rice," Dr Chaudhury says. "Since the genes function as suppressors of partial apomictic development in *Arabidopsis*, what we needed to do was switch these genes off in rice."

To achieve that goal, ACIAR-funded post-doctoral fellow Dr Ming Luo generated transgenic rice lines using a gene-silencing technique developed by CSIRO called RNAi (RNA interference).

"When you silence FIS-class genes, you remove the suppressors and then you observe both autonomous endosperm development and partial embryo development," Dr Chaudhury says.

The next frontier, according to Dr Bennett and Dr Chaudhury, is achieving full embryo production in the absence of fertilisation. "We have a lot of ideas about how to achieve it which we are testing at the moment," says Dr Chaudhury.

He remains optimistic that the ultimate target can be achieved and an increased rice production system can be made available to poor farmers.

"This is one of the most ambitious projects in plant biology," says Dr Chaudhury. "But the international community is once again becoming excited about the possibilities of apomixis and its ability to make seed production so much easier. Of course, once we can do it in rice, it opens the way for apomictic varieties of other cereals." ◀