Scuba rice: breeding flood-tolerance into Asia's local mega rice varieties

Key fact:

New rice varieties tested in India and Bangladesh can survive up to two weeks of complete submergence in water, providing farmers with protection against short-term flooding. The flood-resistant *SUB1* gene, when transferred into popular rice varieties, allows them to retain their characteristics. This research has led to the official release of flood-tolerant local rice varieties across Asia.

Submergence rice varieties at a test site in Bangladesh *(IRRI)*

Summary:

Through collaborative research led by the International Rice Research Institute (IRRI), a flood-tolerant local rice variety was investigated to isolate the gene responsible for flood resistance. Using a technique known as marker-assisted backcrossing, scientists transferred the water tolerant trait of interest into commercially valuable local rice varieties without losing useful characteristics which make them popular with farmers.

Identification of the genetic code of the *SUB1* gene controlling submergence tolerance enabled breeding of new, high-yielding "Sub1 mega-varieties", with popular characteristics such as high yield, good grain quality and local pest and disease resistance. In collaboration with local partners, the varieties have been disseminated across ten Asian countries, and are also being tested in Africa. Further seed multiplication and research into flood tolerance is ongoing, as well as identification of genes for drought and salt tolerance.

Facts & figures[1]

- Over 20% of rice land in Bangladesh is prone to floods which occur every year (IRRI 2008).
- Paddy loss due to flooding in Bangladesh and India alone amounts to an estimated 4 million tons of rice per year - enough to feed 30 million people (Rice Today 2009).
- In 2006, more than 50 provinces in the Philippines were affected by devastating typhoons and floods which cost the rice industry more than 3 billion pesos (US$65 million). In 2008, 23 tropical cyclones hit the country with total cost of agricultural damages of about 12 billion pesos (US$269million)[2].
- The flood tolerant or "scuba" versions of popular rice varieties can withstand about 17 days of complete water submergence (Singh et al. 2009).
- Six Sub1 "mega varieties" of rice have been produced using marker-assisted backcrossing, which enables the flood-tolerant gene *SUB1* to be transferred into valued varieties (Neeraja et al., 2007; Septiningsih et al., 2009).
- Yields of up to three tons per ha have been achieved with Sub1 varieties under flash flood conditions where farmers could not harvest other varieties (Singh et al 2009).
- Seed multiplication of new Sub1 varieties is proceeding in ten countries across Asia in partnership with National Agricultural Research and Extension Systems (Cambodia, Indonesia, Laos, Myanmar, Philippines, Thailand, Vietnam, Nepal, Bangladesh and India).
- Improved and flood tolerant rice varieties have been released in four countries.
- IRRI's Stress-Tolerant Rice for Africa and South Asia programme, which disseminates the Sub1 seed and other drought and salt tolerant rice varieties, aims to raise yields by 50% over ten years through improved cultivars and management, benefiting an estimated 18 million households in target countries.

Scuba rice: breeding flood-tolerance into Asia's local mega rice varieties

Throughout Asia, the annual occurrence of flash floods and typhoons results in heavy production losses in paddy rice. In Bangladesh and India alone such losses amount to an estimated 4 million tons of rice per year - enough to feed 30 million people. Five days of complete submergence will destroy most rice crops, but some rice plants can survive under water for two weeks - plants whose low yields and poor grain quality make them unsuitable as cultivars. However, identification of submergence tolerance displayed by one such plant, an Indian variety called FR13A, has led to successful breeding of submergence-tolerant varieties.

Flash floods and typhoons result in heavy production losses in paddy rice *(IRRI)*

By overcoming the negative impacts of climate change, food security and rice production have been boosted, while dependence on costly rice imports has been reduced. In addition, because plants developed through marker-assisted selection are not genetically modified, the new varieties are not subject to the regulatory testing that can delay release of genetically modified organisms for several years. Improved and flood tolerant varieties of rice have already been successfully released in Indonesia, India, Bangladesh and the Philippines.

Over the last few decades, collaborative research between the University of California and the International Rice Research Institute (IRRI) has led to the development of flood-tolerant, "scuba" versions of popular rice varieties. The research began in the 1970s when flood-resistant varieties of rice were identified in India. Researchers then crossed and improved the tolerant characteristics to produce higher-yielding rice varieties, which can withstand up to 17 days of complete submergence.

Using a technique known as 'marker-assisted backcrossing', scientists were able to transfer one single trait of interest into commercially valuable rice varieties without losing useful characteristics - such as high yield, good grain quality or pest and disease resistance. Typically during a flood, rice plants will extend the length of their leaves and stem in an attempt to escape water submergence. In 2006 the gene *SUB1A*, derived from an India rice variety grown in Orissa, was isolated and the genetic code controlling submergence tolerance was identified. The *SUB1A* gene is activated when the plants are submerged, effectively making the plant dormant, allowing it to conserve energy until the floodwater recedes. This gene also induces tillering once water has receded.

***Swarna* is the number one rice variety in India** *(IRRI)*

Six rice "mega varieties" - flood-tolerant versions of high yielding local rice varieties, popular with farmers and consumers - were tried and tested on farmers' fields across the region. The first variety developed, *Swarna-Sub1*, showed high survival under submerged conditions compared to the original variety *Swarna*, and gave yield advantages of one to three tons per hectare over *Swarna* when submerged. *Swarna* is the number one rice variety in India producing a high yield, good grain eating quality and requires 25 per cent less nitrogen, as widely claimed by the farmers. Released in Andhra Pradesh in 1982, it spread across the sub-continent and into Bangladesh, where it was never officially released. It is now the number two variety there during the wet season.

However, the improved *Swarna-Sub1* variety is now targeted to replace *Swarna* on some 5 to 6 million hectares of rice in eastern India and Bangladesh. The new varieties are effectively identical to their susceptible counterparts but recover after severe flooding, making them ideal to replace popular varieties in flood-prone areas. Seeds have been disseminated and released through the IRRI Stress Tolerant Rice for Poor Farmers in Africa and South Asia (STRASA) programme, which aims to increase yields by 50 per cent and benefit an estimated 18 million households through improved cultivars and management practices over ten years. In some areas the variety has increased yields by up to three tons per hectare, leading to higher incomes. Although it was released in India in 2009 and in Bangladesh in 2010, during 2009 this variety was cultivated by approximately 10,000 farmers in these two countries. During 2010 this number is expected to grow by more than 20 fold.

Farmers' preferences have been monitored through on-farm selection by farmers *(IRRI)*

Farmer's preferences have been monitored through on-farm selection by farmers and the development of new Sub1 varieties is now underway in Cambodia, Indonesia, Lao PDR, Myanmar, Thailand, Vietnam and the Philippines, in partnership with National Agricultural Research and Extension Systems (NARES). Working with a wide range of partners has helped to make new improved varieties available. Strong support from national systems has been a key factor in the success of the project and in benefiting the poor. Training for farmers has also helped improve practices for weeding, drying and storing to improve quality of their own seed. Pre-release promotion of new varieties has helped farmers to be aware and demand seed, providing the necessary stimulus for seed companies to invest in new varieties. Bangladesh is also in the process of changing national seed policy to allow the private sector organisations to release their own varieties, which will also impact on the choice offered to farmers.

Salt tolerance has already been introduced into Sub1 varieties and the introduction of drought tolerance and tolerance to stagnant flooding is currently being examined. In a few years, it is expected that further genes will be identified including for anaerobic germination for direct seeding under water in flash floods. Identification and combination of these traits in improved varieties will allow higher yielding rice to be grown in a wide variety of conditions.

Testimonials:

- **Mr. Ed Gonzales regional technical director, Department of Agriculture Regional Field Unit 3, Philippines:** "We have planted IR64-Sub1 on about 100 hectares of land in Concepcion, Tarlac, and had an initial harvest of 38 cavans/ha (1,900 kg/ha) in spite of the crop being submerged three times in more than knee-deep water during wet season 2009. This is very positive, and in the next wet season (2010) we will plant IR64-Sub1 on 1,000-1,500 ha."

- **Biplob Sarker, a small farmer of Hamindpur village in Sadullapur upazila, Bangladesh:** Two thousand farmers will get seeds of *Swarna*, a flood tolerant variety of paddy, for cultivation on their land this year as the newly developed variety has seen successful experimental cultivation in Sadullapur upazila of Gaibandha district. "I gave up the hope of getting any yield from my land as paddy seedlings remained submerged for 17 days. But to my surprise the seedlings grew green again after the flood. Still I can't believe I have got 18 maunds (672 kg) of paddy from there."

Additional case study information

Costs and benefits:[3]

In Bangladesh and India alone paddy loss to flooding amounts to an estimated 4 million tons of rice per year - enough to feed 30 million people. In 2006, more than 50 provinces in the Philippines were affected by devastating typhoons and floods, which cost the rice industry more than three billion pesos - about US$65 million. Small-scale producers depend on rice for their livelihoods and such losses impact on national food security while ramping up costs of rice imports. The improved rice varieties boost yield and income.

In Bangladesh, sowing of the flash-flood tolerant varieties could produce an additional 1 million tonnes of paddy annually, making the country more food secure and creating export potential. In India, the State Government of Uttar Pradesh[4], in collaboration with the National Food Security Mission of the Indian Ministry of Agriculture, has initiated an ambitious plan to take *Swarna-Sub1* to 0.5 million ha in the state during the next three years by scaling up seed multiplication and targeted dissemination.

DFID contribution to research:

- Attributed funding on natural resources management and core funding to IRRI over the years to develop the submergence-tolerant varieties was extremely important in developing this research.
- This is an example of how collaborative funding and international research efforts can tackle specific problems to help poor farmers in the wake of changing climatic conditions.

Research milestones:

- 1975-1978 Flood-tolerant rice discovered and crossed to get improved varieties.
- 1991 Improved breeding lines developed combining tolerance and high yield.
- 1995 *SUB1* gene from flood-tolerant varieties mapped to rice chromosome 9.
- 2000 Fine-scale map of *SUB1* completed to apply marker assisted selection.
- 2005 First Sub1 variety developed by marker assisted backcrossing (*Swarna-Sub1*) completed and seed sent to India and Bangladesh for testing.
- 2006 *SUB1A* isolated as the gene responsible for submergence tolerance.
- 2007 *Swarna-Sub1* performs well under natural flash-flooding in farm field tests.
- 2009-10 Improved varieties officially released in India, Indonesia, Philippines, and Bangladesh; other Sub1 varieties under evaluation in over ten countries.

Photo credits:

IRRI: For high res images see IRRI flickr page
http://www.flickr.com/photos/ricephotos/sets/72157619130987855/

Multi-media material:

Flood-proof rice provides relief for poor farmers
http://www.irri.org/flood-proof-rice/

Links:

IRRI: www.irri.org

Main references:

Neeraja, C., R. Maghirang-Rodriguez, A. Pamplona, S. Heuer, B. Collard, E. Septiningsih, G. Vergara, D. Sanchez, K. Xu, A. Ismail, and D.J. Mackill, (2007) A marker-assisted backcross approach for developing submergence tolerant rice cultivars, *Theoretical and Applied Genetics* 115:767-776.

Sarkar, R.K., D. Panda, J.N. Reddy, S.S.C. Patnaik, D.J. Mackill, and A.M. Ismail, (2009) Performance of submergence tolerant rice genotypes carrying the *Sub1* QTL under stressed and non-stressed natural field conditions. *Indian Journal of Agricultural Science* 79:876-883

Septiningsih, E.M., A.M. Pamplona, D.L. Sanchez, C.N. Neeraja, G.V. Vergara, S. Heuer, A.M. Ismail and D.J. Mackill, (2009) Development of submergence-tolerant rice cultivars: the Sub1 locus and beyond**,** 2009, *Annals of Botany* 103: 151-160.

Singh, U.S., M.A. Bari, A. Kumar, A. Ismail and D.J. Mackill, (2010) *Status of Stress Tolerant Rice in South Asia: Proceedings of the Workshop on Public and Private Participation in the Development and Adoption of Stress Tolerant Rice Varieties in the coastal region of Bangladesh*. Organised by the International Finance Corporation and South Asia Enterprise Development Facility, Dhaka, 19 August 2009

Singh, S., D.J. Mackill, and A.M. Ismail, (2009) Responses of *SUB1* rice introgression lines to submergence in the field: Yield and grain quality. *Field Crops Research* 113: 12-23

Other key references:

Ganzon, T., (2009) *Next on your plate: 'Scuba rice'*, CBN News, published on 1 June 2009
http://www.abs-cbnnews.com/lifestyle/06/01/09/next-your-plate-scuba-rice

IRRI, (2008) *From genes to farmers' fields: Waterproof rice set to make waves in South Asia*, published 21 November 2008
http://beta.irri.org/news/index.php/press-releases/from-genes-to-farmers-fields-waterproof-rice-set-to-make-waves-in-south-asia.html

IRRI, (2009) *"Scuba rice" makes a splash in India and Bangladesh*, published 14 April 2009
http://beta.irri.org/news/index.php/press-releases/-scuba-rice-makes-a-splash-in-india-and-bangladesh.html

Philippine Information Agency, (2009) *15 pilot areas in Eastern Visayas soon to harvest flood-resistant rice*, published 10 November 2009
http://greenbio.checkbiotech.org/news/15_pilot_areas_eastern_visayas_soon_harvest_flood_resistant_rice

The New Nation, (2009) *FFTV can produce 60 lakh tonnes additional paddy*, published 25 September 2009
http://nation.ittefaq.com/issues/2009/09/25/news0980.htm

Bangladesh Economic News, (2009) *Submergence tolerant rice-BR-11-sub-1 to be released this year*, published 11 September 2009
http://bangladesheconomy.wordpress.com/2009/09/11/submergence-tolerant-rice-br-11-sub-1-to-be-released-this-year/

Lazaro, R.E.R., (2009) *Submergence-tolerant rice variety now available to local farmers*, Business Mirror, published 9 August 2009
http://www.businessmirror.com.ph/index.php?option=com_content&view=article&catid=53:agri-commodities&id=14319:submergence-tolerant-rice-variety-now-available-to-local-farmers

Contact for further information:

Sophie Clayton
Public Relations Manager
International Rice Research Institute
DAPO Box 7777
1301 Metro Manila
Philippines
Tel: +63 (2) 580-5600
Fax: +63 (2) 580-5699
Email: s.clayton@cgiar.org

[1] Unless otherwise indicated, facts and figures sourced from: www.irri.org/flood-proof-rice
[2] ESCAP/WMO Typhoon Committee, (2009) *Member Report: Republic of the Philippines*, 41st Session, Chiang Mai, Thailand http://www.typhooncommittee.org/41st/docs/TC2_MemberReport2008_PHILIPPINES1.pdf
[3] Singh, U.S., M.A. Bari, A. Kumar, A. Ismail and D.J. Mackill, (2010) Status of Stress Tolerant Rice in South Asia, Proceedings of the Workshop on Public and Private Participation in the Development and Adoption of Stress Tolerant Rice Varieties in the coastal region of Bangladesh. Organised by the International Finance Corporation and South Asia Enterprise Development Facility, Dhaka, 19 August 2009
[4] Minutes of Meeting of Scientists of Agriculture Universities and Departmental officials in relation to Kharif seed arrangement 2010 held on 05.02.10 and chaired by Principal Secretary (Agriculture), Govt of Uttar Pradesh

DFID Department for International Development

DFID, the Department of International Development, is the part of the UK government that manages Britain's aid to poor countries and works to get rid of extreme poverty.

WRENmedia on air... on line... in print... in person...

This case study has been commissioned by DFID and produced by WRENmedia, as part of a series demonstrating the impact of DFID's funding to agricultural research. The views expressed do not necessarily reflect the Department's official policies.