Creating genetic markers to breed downy mildew and drought resistant pearl millet

Key fact:

Two million people enjoy improved food security thanks to a collaborative research programme which used molecular genetic tools to develop an improved pearl millet hybrid more resistant to the disease downy mildew.

Summary:

Food security in some of the hottest, driest and least food secure areas of India is threatened by downy mildew disease, which causes 30 per cent production losses nationwide in pearl millet at a cost of some US$8 million during regular disease outbreaks. Between 1990 and 2005 new techniques of genetic marker-aided selection (MAS) helped to advance the development of pearl millet hybrids more resistant to this disease.

Breeders improved downy mildew resistance of the parental lines of an existing popular hybrid through conventional and marker-aided selection. The laboratory process accelerates the development of one improved parent by several years, without the need for testing in the field. A resulting hybrid, evaluated and chosen by farmers, is both more downy mildew resistant and higher yielding, and is now available around the country and promises to protect farmers from the past "boom-bust" cycle of pearl millet hybrid cultivation in India. Further improvement of this hybrid for new traits such as improved drought tolerance using this technology is underway.

A new improved pearl millet hybrid *HHB 67 Improved* is more resistant to downy mildew *(ICRISAT)*

Facts & figures[1]

- Severe downy mildew (DM) attack can result in up to 30% loss of pearl millet grain and stover harvest. Scant and unreliable rainfall is another factor that drastically reduces pearl millet yield and yield stability.
- The hybrid *HHB 67 Improved* is the first product of marker-assisted breeding to reach cereal producers in India.
- The conventional backcross transfer of DM resistance to female parent 843A/B took nearly nine years (1991-1999), while marker-assisted backcross transfer to improve the male parent H 77/833-2 took just over three years (1997-2000).
- More than 500,000 hectares in Haryana and Rajasthan were sown with *HHB 67 Improved* during the 2009 rainy season, benefiting hundreds of thousands of farm families.
- Adopting *HHB 67 Improved* can prevent potential losses of US$8 million annually across Haryana and Rajasthan due to DM, with additional benefits to farmers from its improved grain and stover yield potential.
- Breeding enhanced drought resistance in this hybrid would further increase pearl millet yield and food security.
- Hybrid seed-producing farmers earn net profits of Rs 22,500-25,000 (about US$650) per ha through hybrid seed production. As hybrid seed production occurs in other regions/seasons than the main millet crop, benefits are provided to an additional set of farm households.

Creating genetic markers to breed downy mildew resistant pearl millet

Pearl millet (*Pennisetum glaucum*) is grown for grain and stover (dry fodder) in some of the hottest and driest areas of Africa and South Asia. In India, genetically uniform single-cross hybrids are grown on at least 70 per cent of the 9 million hectares sown to this crop. These uniform single-cross hybrids are particularly vulnerable to downy mildew (DM), a disease caused by the pseudo-fungus *Sclerospora graminicola*, a close relative of the pathogen responsible for the Irish potato famine of the 1840s. As the crop is grown rainfed, scant and unreliable rainfall is an additional factor that drastically reduces yield and yield stability.

Downy mildew is the single most destructive pearl millet disease *(ICRISAT)*

Downy mildew is the single most destructive pearl millet disease, and during regular outbreaks in India it can cause national production losses of up to 30 per cent. More importantly, this crop stands between famine and food sufficiency for many farming families.

A DFID-funded programme supporting collaborative research between ICRISAT and the Institute of Biological, Environmental and Rural Sciences (IBERS) between 1990 and 2005 helped to breed improved hybrids of pearl millet more resistant to DM. The breeding process that gave rise to the hybrid *HHB 67 Improved* used a combination of traditional techniques and the high tech method of genetic marker-aided selection (MAS). DM resistance maintenance breeding is an attempt to break the “boom-bust” cycles that have characterised pearl millet hybrid cultivation in India since the late 1960s. More recently, a co-funded DFID and BBSRC project under the Sustainable Agriculture Research for International Development (SARID) initiative aims to further improve yield of pearl millet under drought conditions.

The original hybrid *HHB 67* was a particular favourite of women farmers because it provided a more reliable source of food grain early in the rainy season than longer-duration hybrids or traditional landrace varieties of this cereal. This preference was noted especially among female participants in on-farm evaluation of pearl millet cultivars in Rajasthan during the mid-1990s, and it was partially on the basis of this preference by women that the original *HHB 67* was selected for further improvement. This hybrid became the starting point for the first attempt at marker-assisted improvement of DM resistance in pearl millet.

Farmers viewing *HHB 67 Improved* seed multiplication plots *(ICRISAT)*

This breeding effort was guided by genetic markers called restriction fragment length polymorphism (RFLP) markers developed in a UK laboratory. This technique allows researchers to identify resistance traits in the laboratory through analysis of the plant's DNA, a much faster and more reliable process than running trials in the field. The conventional backcross transfer of DM resistance took nearly nine years (1991-1999), while marker-assisted backcross transfer was completed in just over three years (1997-2000), once the markers had been developed and marker-trait associations established (1990-1996).

Greenhouse disease screening of the new parental stock took place at ICRISAT in Patancheru, Andhra Pradesh. This was followed by field testing of two cultivars across six sites in Haryana, Rajasthan and Andhra Pradesh, which confirmed the DM resistance. Farmers expressed a clear preference for one of the two improved hybrids, which yields 5-10 per cent more grain and stover than the original *HHB 67* and is also more resistant to DM.

In pearl millet evaluations male farmers have tended towards taller, later maturing varieties, as these produce more fodder for their livestock, and the men (being fed first in traditional households) are often not as aware as their wives of the food grain shortages that typically come with the sowing of the rainy season crop. Compared to the original *HHB 67*, fortunately, the improved version is about 30 cm taller, producing more fodder than the original. Thus it is more attractive to male farmers while still serving women's interests.

***HHB 67 Improved* is more attractive to male farmers, whilst still favoured by women** *(ICRISAT)*

In 2005, after three years of obligatory testing in national trials, the Haryana State Varietal Release Committee approved release of this improved version of *HHB 67* for cultivation in Haryana. India's Central Plant Variety Release Committee followed the same year in approving an All-India Release. *HHB 67 Improved* was the first product of DNA marker-assisted breeding to reach cereal producers in India. The technologically advanced research has brought greater food security to around 2 million people, who grew the previously popular but DM susceptible variety *HHB 67* and whose crops were previously at risk from DM.

Further research funded by the DFID and BBSRC on pearl millet is currently combining additional traits, such as increased drought tolerance, in the *HHB 67 improved* developed in 2005. Resulting varieties will help to further improve the yield and yield stability of pearl millet for resource poor farmers of the arid and semi-arid desert margins of tropical and subtropical South Asia and sub-Saharan Africa.

Additional case study information

Costs and benefits:[2]

- By adopting *HHB 67 Improved*, farmers in Haryana and Rajasthan can avoid grain production losses of US$7.8 million, which would be expected in the first year of a major DM outbreak on the original *HHB 67*. This estimate does not include the additional value of straw production or the increased grain and stover yield potential of *HHB 67 Improved*.
- Assuming an average farm size of two hectares, with each farm supporting a family of eight, the improved variety is increasing the food security of up to 2 million people.
- The annual savings to Indian farmers as a result of cultivating *HHB 67 Improved* are equivalent to the total funding provided by DFID between 1990 and 2005 to support the development and application of the marker-assisted breeding tools for pearl millet.
- The seed multiplication of a hybrid itself creates incomes for farmers, including women. In Nizamabad District of Andhra Pradesh State, farmers produce more than 70 per cent of the country's pearl millet hybrid seed, with profits estimated at US$5 million every season.

DFID contribution to research:

A series of research grants from DFID's Plant Science Research Programme largely funded marker development, linkage map construction, and initial disease resistance QTL discovery was conducted in the UK; marker-assisted backcross improvement of hybrid parental line DM resistance at ICRISAT; and initial trials by ICRISAT and its national programme partners to identify the best improved hybrids. More than 15 years of support from DFID was a critical contributing factor to this success story.

Further funding by DFID under the BBSRC Sustainable Agriculture Research for International Development (SARID) initiative will look at genes and gene behaviour in different conditions to develop tools to simplify and increase the precision of breeding for increased drought tolerance in pearl millet. Their findings will help play a significant role in increasing crop production not only for pearl millet but also for other crops grown in water-stressed environments globally.

Research milestones:

- 1990-1995 Creating and mapping RFLP-based markers for pearl millet, then identifying marker-trait associations for resistance to DM.
- Mid-1990's On-farm evaluation of three pearl millet cultivars - women prefer extra-early *HHB 67* so this is selected for improvement.
- 1997-2000 Marker-assisted backcrossing to improve parents of *HHB 67*, and initial hybrid testing.
- 2001 Initial target environment assessment of “improved” hybrids in Haryana and Rajasthan.
- 2002 Three year on-station trial evaluation initiated (required for governmental approval).
- 2005 *HHB 67 Improved* released by Indian government for commercial cultivation.
- 2006 Seed multiplication for 30,000 hectares and initial marketing in Haryana and Rajasthan; outbreaks of DM stimulate farmer interest.
- 2008 Four-year SARID project for investigating drought tolerance launched.
- 2007-2009 Seed multiplication increases from 60,000-100,000 hectares to more than 500,000 hectares.
- 2010 Seed for up to 700,000 hectares (approx 350,000 farm families) anticipated.

Photo credits:

ICRISAT: For high res images contact CT Hash and L Vidyasagar (c.hash@cgiar.org)

Links:

ICRISAT: www.icrisat.org

Main reference:

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[1] Facts and figures sourced from: Hash *et al* (2006) *Teamwork delivers biotechnology products to Indian small-holder crop-livestock producers: Pearl millet hybrid "HHB 67 Improved" enters seed delivery pipeline*, ICRISAT
[2] Hash *et al* (2006) *Teamwork delivers biotechnology products to Indian small-holder crop-livestock producers: Pearl millet hybrid "HHB 67 Improved" enters seed delivery pipeline*, ICRISAT

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.

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