# Pre-breeding and wheat re-synthesis

**NIAB's flagship wheat re-synthesis programme recreates the original rare hybridisation events that happened in the Middle East 10,000 years ago between an ancient wheat and wild grass species. This original crossing provides the genetic basis for today's modern wheat (*Triticum aestivum*) varieties. Re-synthesised wheat (also called Synthetic Hexaploid Wheat, or SHWs) are fully crossable with modern wheats, and are an excellent bridge for transferring useful genetic diversity from wild relatives into modern UK wheat.**

## How are they created?

SHWs are developed by crossing durum (pasta) wheat (a tetraploid) and wild goatgrass (a diploid). The first step is to make a cross in the greenhouse, just like any breeding programme.

Pollen from wild goatgrass (*Aegilops tauschii*) is placed onto prepared ears of durum wheat (*Triticum turgidum durum*). Seeds begin to form which are then removed from the durum wheat ears. In the lab these immature seeds are dissected and the tiny seed embryos are transferred onto a petri dish to germinate.

When the resulting small plants are strong enough they are treated with colchicine to double the chromosome number, and then grown on in pots to produce mature plants and ultimately, seed. The process does not use GM technology.

This seed is the re-synthesised wheat, or SHW, which can be used in standard crosses with other wheat varieties.

## Is NIAB the first to develop synthetic wheat?

No, the original SHWs were generated at CIMMYT, the international wheat and maize improvement centre based in Mexico, which ran an extensive programme of SHW development in the 1980s.

CIMMYT carries out a host of important wheat breeding research especially for the developing world. The CIMMYT SHWs have already been successfully used in wheat breeding around the world, especially by breeders working in drought prone, lower yielding, extensive agriculture systems in China, Australia, Africa, the Indian sub-continent, and South/Central America. But the UK and much of Europe has been slow to explore their potential.

## Modern Wheat

*Aegilops speltoides* (BB) **X** *Triticum urartu* (AA)

↓ Chance hybridisation

**Wild Emmer** *Triticum dicoccoides* (AABB) **X** **Wild Goat Grass** *Aegilops tauschii* (DD)

↓ Chance hybridisation

**Modern Wheat**
*Triticum aestivum*
(AA, BB, DD)

## Wheat re-synthesis

**Durum Wheat** *Triticum turgidum durum* (AA, BB) **X** **Wild Goat Grass** *Aegilops tauschii* (DD)

↓ Controlled hybridisation

unstable triploid F1 (ABD)

↓ Chromosome doubling

**Stable SHW**
(AA, BB, DD)

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## Why do we need wheat resynthesis?

From the early domestication of primitive wheat through to modern systematic breeding programmes, wheat yields have increased massively. However, many major wheat producing countries have recently reported a slowing in this progress, leading to concerns for future food security. The national average UK wheat yield has stalled at around 8 t/ha for the past 12 years.

The germplasm pool available for crop improvement constantly requires reinvigorating, with breeders always striving to find new sources of genetic diversity. NIAB's wheat resynthesis work, together with approaches based on other wild and cultivated relatives of wheat, provide the raw materials for exploring this diversity. Our pre-breeding approach transfers this untapped variation into UK-adapted genetic backgrounds and identifies the most promising leads for commercial breeders to exploit in their own programmes. This offers potential new sources of yield improvement, drought tolerance, disease resistance and input use efficiency.

## How is NIAB using SHWs?

NIAB's work is the first systematic exploration of SHWs in temperate, high-input cropping systems like the UK.

The scale of our pre-breeding work is closer to that of a commercial breeding programme than a typical academic research project; when we crossed the original CIMMYT SHWs with UK varieties, we produced and evaluated 5,600 lines, and took 1,000 forward to yield testing. The best of these are being explored further in collaboration with leading UK breeders.

NIAB is now developing novel SHWs using different goatgrass sources to the CIMMYT SHWs, which will access different combinations of genes to the original SHWs. These are being crossed into UK varieties to produce thousands more pre-breeding lines for testing and evaluation. Results from these lines will be available from 2016 onwards.

**NIAB is also crossing modern UK wheat varieties with different related species (durum, wild emmer, cultivated emmer and rivet wheats) without the need to develop SHWs, again to find new sources of genetic material.**

**The plan is to use all this material in screening experiments to provide breeders with material adapted to the challenges of the future, with restrictions on pesticides and fertilisers coupled with projected climate change.**

## Can SHWs bring yield improvements?

In early-stage yield trials of 1,000 lines derived from CIMMYT SHWs, several lines showed genuine yield potential. In 2012, yield increases of up to 30% above the adapted wheat parent were observed. This is the kind of step change in yield potential that will be needed if we are to break away from the incremental yield gains of 0.5% per year that current varieties are providing. This was despite the cold, wet season where lack of sunlight depressed yields – a far cry from the drought-prone conditions in which CIMMYT SHWs have shown their worth before. The best of these lines are currently undergoing a comprehensive matrix of multi-location tests to further explore their yield, agronomy, disease resistance, quality and varietal purity.

New material, based on NIAB's own SHWs, is still at a very early stage but several combinations are showing promise in observation nurseries.

## What next for NIAB SHWs?

If all goes well with further tests and trials, the lead material could enter National List trials in September 2015, which means that there could be varieties on-farm from autumn 2019 onwards. However, as this was experimental material, it is more likely that these lines will also carry some basic faults. Our breeder partners can fix these faults through designed crossing and selection in their own programmes, with resulting varieties emerging from 2022 onwards.

Our newer pre-breeding work will also be much more likely to identify promising parental material than finished varieties.

## How has the work been funded?

The original pre-breeding work was funded by the BBSRC under their Crop Science Initiative, with additional industrial funding from three leading breeding companies, the HGCA and the NIAB Trust.

A BBSRC 'Super Follow-On Fund" award has just been granted in which the best of the original pre-breeding lines will be further tested and moved towards potential commercialisation and release as varieties on farm. This extension has considerable in-kind contributions from the three breeders involved in the project (KWS, Limagrain and RAGT), and any income arising from commercialisation will be shared to reflect this unique public/private breeding partnership.

NIAB's work on developing its own SHWs, based upon *A. tauschii* sources that have not been previously exploited, forms part of the BBSRC's £7 million investment into public sector pre-breeding in wheat (www.wheatisp.org).