Synthetic hexaploid wheat

The synthetic hexaploid wheat (SHWs) programme at NIAB 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. SHWs are fully crossable with modern wheats, and are an excellent bridge for transferring useful genetic diversity from wild relatives into modern UK wheat.

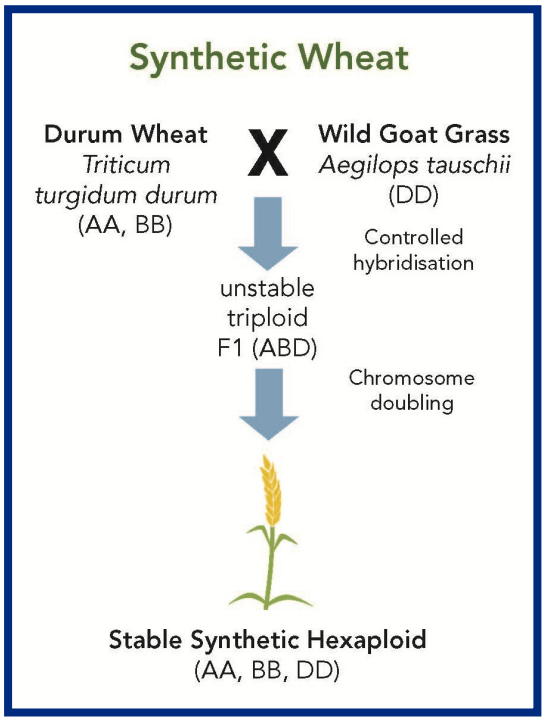
How are they created?

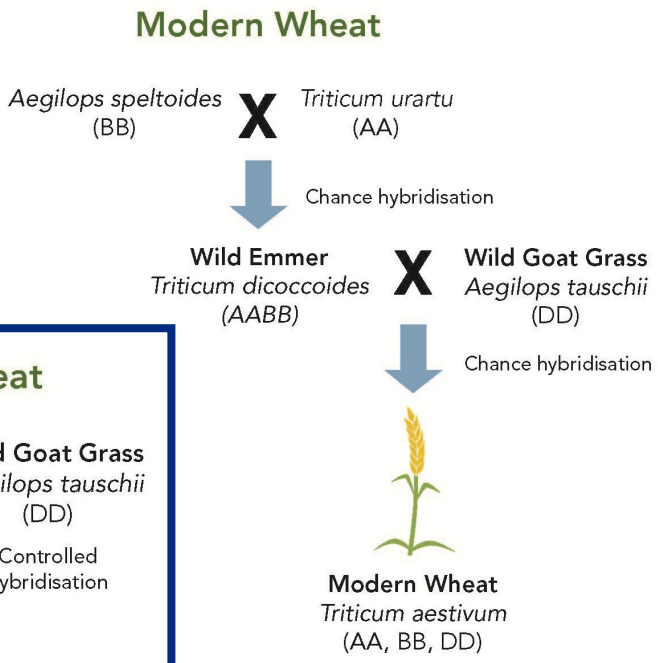
SHWs are developed by crossing durum (pasta) wheat (a tetraploid) and wild goat-grass (a diploid). The first step is to make a cross in the greenhouse, just like any breeding programme.

Pollen from wild goat grass (*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 Synthetic Hexaploid Wheat which can be crossed directly with any wheat variety.





Why do we need synthetic wheats?

Over the next 50 years, the world needs to grow more wheat than has been produced in the 10,000 years since agriculture began.

Over the years, domestication of the wheat plant has increased yields, but recently those increases have slowed leading to concerns for future food security. The national average UK wheat yield has stalled at around 8t/ha for the past 12 years.

This slow-down is partly because domestication has eroded wheat diversity and the possibilities for improvement from within the current germplasm pool are reaching a limit.

Recreating that initial hybridisation with from wild and cultivated relatives of wheat, including goat grass, emmer wheat and durum wheat, has enabled plant scientists at NIAB to introduce novel sources of genetic diversity, capturing some of the variation from those ancient wild relatives lost during the domestication of wheat as agriculture evolved.

When bred conventionally into modern wheat varieties these offer potential new sources of yield improvement, drought tolerance, disease resistance and input use efficiency.

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.

@niabtag • info@niab.com • 01223 342200 • niab.com

How is NIAB using SHWs?

NIAB's work is the first systematic exploration of SHWs in temperate, high-input cropping systems like the UK. When we crossed the original CIMMYT SHWs with UK varieties the field trial yield, disease resistance and quality results were better than expected, even with reduced fertiliser levels.

While SHWs may previously have been produced in the UK and Europe on a very small scale by academics, NIAB is the first to develop large-scale research, closer to that of a commercial breeding programme. A typical academic research programme would involve a single population of perhaps 100-250 lines, but NIAB has produced and evaluated 5,600 lines, taking 1,000 forward to yield testing.

NIAB is now developing its own SHWs and crossing them into UK varieties using different goat-grass sources to the CIMMYT SHWs to access different combinations of genes to the original SHWs, and producing 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 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.

Durum wheat ears are emasculated, removing the anthers, and pollinated with wild goat-grass. The cellophane bag prevents contamination by any stray pollen.

Do NIAB SHWs show yield improvements?

Based on early-stage trials, NIAB is confident that the performance gains and level of potentially valuable variation observed – through this novel step of re-synthesising the original wheat plant – points to a major transformation in the wheat improvement process.

In 2012, yield increases of up to 30% were produced in early field trials. This was despite the cold, wet season where lack of sunlight depressed yields – a far cry from the drought-prone conditions in which these SHWs have shown their worth before.

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%/yr that current varieties are providing.

What next for NIAB SHWs?

The synthetic wheat project also opens up a new model for translational science in the UK, with a partnership agreement already in place between NIAB and three commercial wheat breeders to allow exploitation of the research outputs in commercial breeding programmes, accelerating its uptake and transfer onto UK farms.

This means that there could be a variety on-farm from 2019 onwards.

However, it usually takes 7-10 years from first cross to the variety being grown by farmers), so it is more likely to be from 2022 onwards.

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).

@niabtag • info@niab.com • 01223 342200 • niab.com