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SLIMERS

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Slug Resistant Wheat

How farmers, scientists and citizen scientists worked together to understand slug resistance in wheat

The problem with slugs

Slugs are arable farming's biggest pest, estimated to cost the UK industry about **£43.5M per year**. Since the ban on metaldehyde, there has been only one form of chemical control for slugs – ferric phosphate pellets. Protecting the longevity of this will require both a strategic and precision approach to slug management.

SLIMERS – Strategies Leading to Improved Management and Enhanced Resilience against Slugs – was a three-year project which combined expertise from seven partner organisations. The project partners aimed to advance understanding and develop high-tech slug monitoring, forecasting and patch/spot treatment for both conventional and alternative biocontrol agents while also advancing understanding of slug resistance in wheat.

This knowledge guide outlines how scientists, farmers and citizen scientists worked together to develop understanding of slug resistance in wheat – from the screening of historic landrace varieties through to the discovery of the genomic regions linked to resistance against grey field slugs.

Slug resistant wheat varieties, which could be a total game changer for arable farmers, are now on the horizon thanks to the efforts of everyone involved in the project.”

Tom Allen-Stevens, managing director of the British On-Farm Innovation Network (BOFIN) and SLIMERS project lead.



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The journey to slug resistant wheat

The story of slug resistant wheat has its roots in one of the world's most important collections of wheat genetic diversity – the Watkins Collection.

Established in the early 1900s by Arthur Watkins at the University of Cambridge, the collection contains more than 800 traditional wheat landraces gathered from across the world. Expertly preserved and managed for more than a century, the collection is now

held within the John Innes Centre's Germplasm Resource Unit on the Norwich Research Park.

The collection's landraces are a 'treasure trove' of genetic variation, with traits that have been lost through decades of modern crop breeding.





How the feeding trials worked

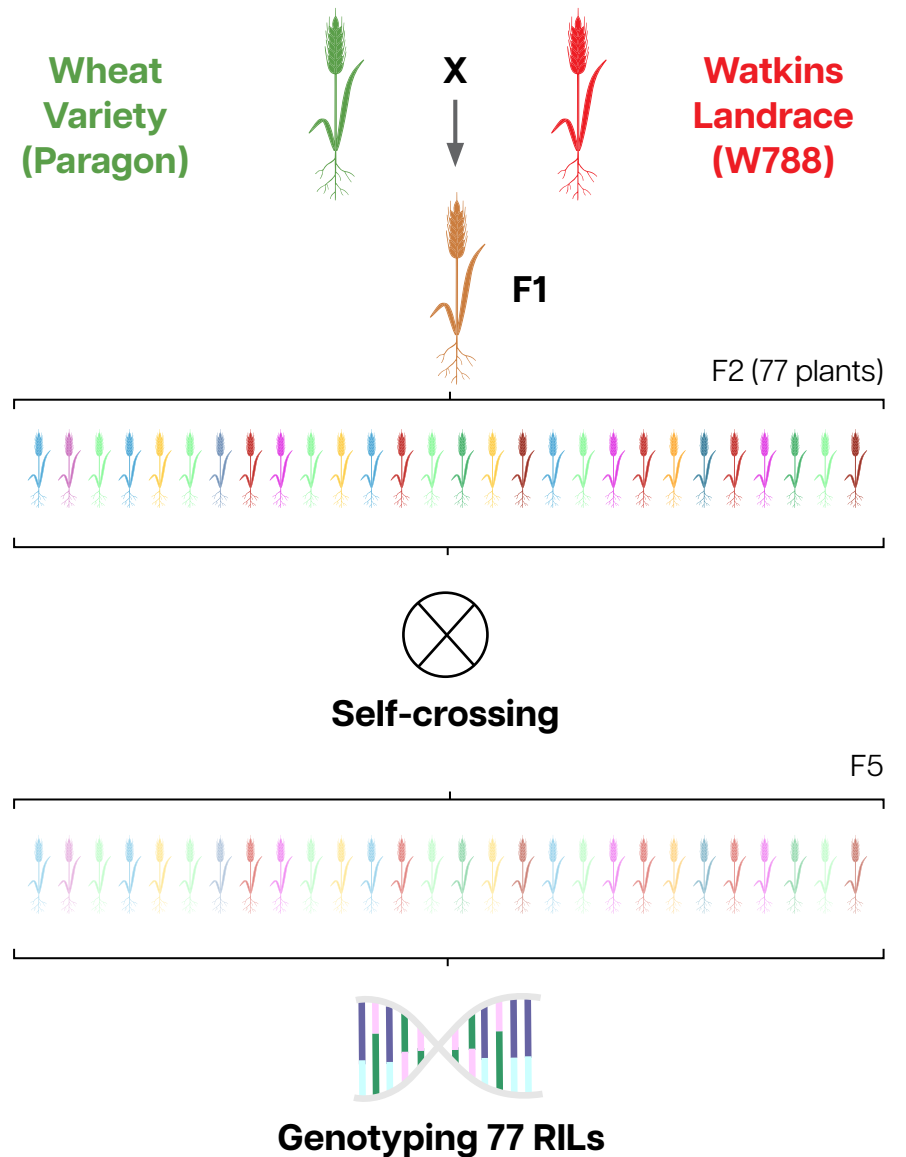
Slug feeding experiments at the John Innes Centre were designed to show how grey field slugs responded to different wheat lines under controlled conditions.

Early 'choice assays' allowed slugs to choose between different wheat varieties, helping identify lines that experienced either high or low feeding damage. As Watkins 788 showed lower levels of grazing compared to

commercial varieties it was the focus of the trials.

The scientists developed 77 Recombinant Inbred Lines (RILs). These are stable wheat lines containing different combinations of DNA from the two parent varieties Watkins 788 and the modern commercial wheat variety Paragon.

Recombinant Inbred Lines (RILs)



Researchers eventually tested all 77 RILs alongside their parent lines.

In ‘no choice assays’ (used in the pre-SLIMERS testing) slugs were offered seeds from a single line, while the SLIMERS study used ‘choice assays’. These were where slugs could select between different lines. Together they helped researchers understand both slug preference and the level of damage each wheat line could withstand.

The researchers measured feeding damage after 24 and 48 hours and monitored seed germination after four days. In total, the experiments generated almost 12,000 data points for damage and nearly 6,000 more for germination scoring.

The slugs used in the trials came from two sources:

- Some were collected from farms and gardens around the UK by farmers and citizen scientist Slug Scouts
- The rest were bred and maintained in colonies at the John Innes Centre insectary.

According to Dr Victor Soria-Carrasco, laboratory and field experiments each brought different strengths. Laboratory testing allowed precise control of variables and made it easier to detect small differences between wheat lines. Field trials, meanwhile, showed how those differences performed under real commercial conditions where weather, soils and slug pressure varied from farm to farm.



“Once we had identified that Watkins 788 was potentially slug resistant the obvious question was ‘what is the genetic basis of that?’ Once we know what genes are responsible for that resistance we can use that information to improve commercial varieties.”

Dr Victor Soria-Carrasco,
Head of Entomology, John Innes Centre



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Future selection for slug resistance

The experience of Victor and his team in the John Innes Centre insectary has culminated in the development of robust protocol for testing wheat varieties for slug resistance. Another successful output of the SLIMERS project, this screening tool can be used by plant breeders to assess and select future wheat lines.

How scientists found the resistance genes

As the 77 RILs in the study had already been genetically sequenced, the John Innes Centre scientists, led by Dr Simon Griffiths, could compare:

- How much slug damage each line suffered, and
- Which genetic regions each line carried.

This process of matching slug resistance with specific parts of the genome is known as **Quantitative Trait Loci (QTL)** analysis. It identified multiple loci across the wheat genome linked to slug damage resistance.

Among these, chromosome 2A, 3A and 7D emerged as promising candidates for future research and validation:



Watkins 788 has two slug resistance genes (chromosome 2A and 3A)

Moderately slug resistant

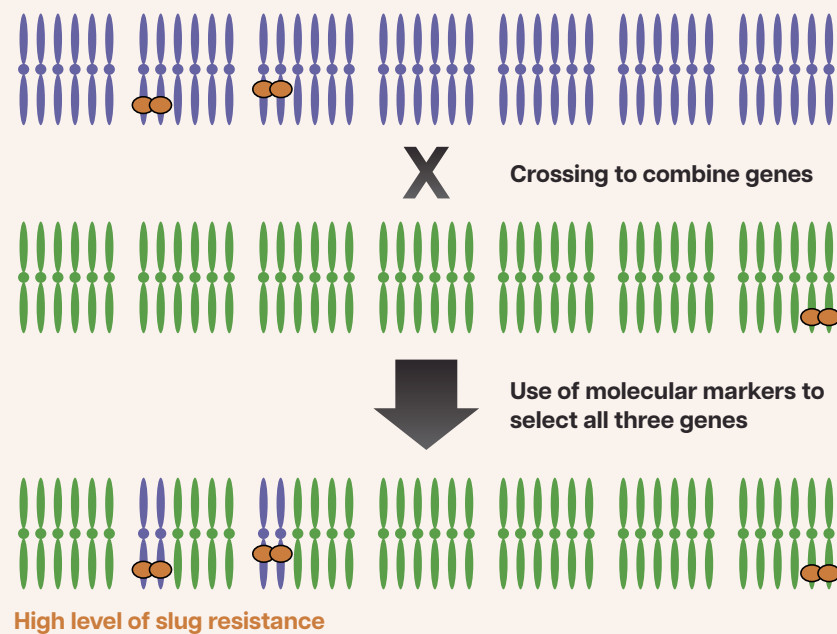


Paragon has one slug resistance gene (chromosome 7D)

Low level of slug resistance

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Combining all three resistance genes therefore achieves the highest possible level of slug resistance – using molecular markers identified in SLIMERS:



“From the thousands of data points collected in the feeding trials we have identified specific molecular markers – parts of the chromosome – where there is reduced slug damage. Plant breeders can now select for those markers to produce a slug-resistant variety.”



Dr Simon Griffiths, John Innes Centre

The Slug Sleuths

The Slug Sleuth farmers played a central role in SLIMERS. Their main task was monitoring slug populations to provide scientists at Harper Adams University with data for developing their slug patch prediction model. Several farmers also took on the additional role of testing potentially slug-resistant wheat lines on their farms.

The aim of the slug-resistant wheat trials was to explore whether the apparent resistance identified in the lab would be seen on farm, and whether the effect was strong enough to be useful to plant breeders.

Trial sites were carefully selected in fields with a known history of slug problems. Farmers drilled the test plots according to detailed protocols, with each trial containing replicated plots of the different wheat lines separated by buffer strips. Slugs were placed within each plot to monitor slug activity throughout the season.

Importantly, no slug pellets were applied to the trial areas, allowing natural slug pressure to reveal any differences between the wheat lines. Apart from this, the trial areas were managed in the same way as the surrounding commercial crop.

The Slug Sleuth farmers recorded crop establishment, slug activity and levels of damage using the BOFIN Triallist app, providing researchers with valuable field-scale data from a wide range of soil types, climates and farming systems across the country.



Their observations and trial results helped validate the laboratory findings and identify which wheat lines were consistently less palatable to slugs under commercial growing conditions.

The Slug Sleuth trials demonstrated the power of

farmer-led research, helping bridge the gap between laboratory discoveries and practical slug solutions. The project also developed field protocols for monitoring slug activity and assessing varietal resistance that will support future research and breeding programmes.



“Slug resistant wheat varieties could be very useful – especially following crops like oilseed rape.”

Lucy Tallis, Slug Sleuth (Leicestershire)

“If slugs aren’t keen on feeding on wheat, then we won’t have to spend so much time and money controlling them.”

Charles Paynter, Slug Sleuth (Bedfordshire)

“We have always suffered high slug numbers and always suspected it was related to our soil type so I was keen to find out more by joining SLIMERS. Any potential reduction in slug control cost is very welcome.”

Tom Jewers, Slug Sleuth (Suffolk)

The Slug Scouts

While the Slug Sleuths were testing wheat lines in the field, farmers and citizen scientists known as 'Slug Scouts' supported the laboratory research by collecting and posting grey field slugs from across the UK to the John Innes Centre. These slugs were used in the feeding trials and to establish breeding colonies for ongoing experiments at the Centre.

The Slug Scout campaign attracted strong interest following national media coverage of the project, with thousands of gardeners, schools and families signing up to collect and post slugs to the SLIMERS researchers. The response meant the research used slugs from a wide range of locations and environments across the country, ensuring the trials reflected a range of slug populations.

As well as providing valuable resource for the research, the Slug Scout campaign helped raise awareness of the challenges slugs present to arable farmers and demonstrated how citizen science can make an important contribution to agricultural research.



A huge thank you to all our Slug Scouts and Slug Sleuths. The advances made through this project would not have been possible without your contributions.

What happens next?

The discovery of the three genomic regions linked to slug resistance gives breeders powerful new tools to develop commercial wheat varieties that slugs are less likely to damage.

By using the screening protocol developed by Dr Victor Soria-

Carrasco and colleagues, plant breeders can test developing varieties for slug resistance earlier in the breeding process.

Plant breeders can test developing varieties for slug resistance earlier in the breeding process (see diagram opposite).



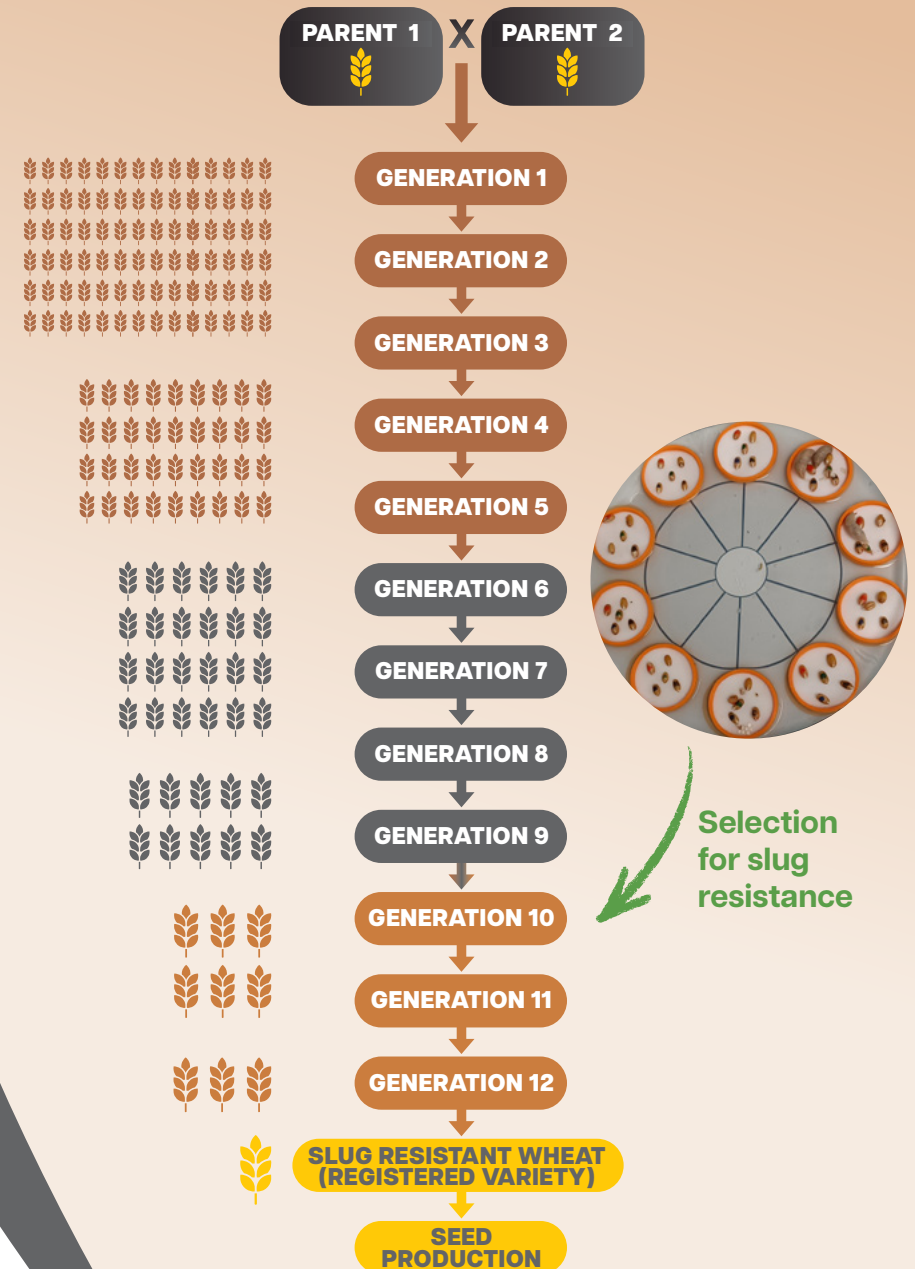
Plant breeders now have clear genetic targets and a screening protocol to work with, bringing the prospect of varieties naturally more resistant to slug damage a significant step closer to reality.

For farmers facing increasing pressure from slugs and with only one remaining chemical control

option, that offers real hope that fully resistant wheat varieties are now within reach.

Above all, SLIMERS has demonstrated what can be achieved when farmers and scientists work together to tackle some of agriculture's biggest challenges.

Selecting for slug resistance in a wheat breeding programme using assays developed in SLIMERS





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About SLIMERS

Strategies Leading to Improved Management and Enhanced Resilience Against Slugs (SLIMERS) was a three-year £2.6M research programme involving more than 100 UK farms and six partners.

BOFIN (British On-Farm Innovation Network) led the consortium which included partner organisations UK Agri-Tech Centre (technical lead), Harper Adams University, John Innes Centre, Agrivation, Fotenix and Farmscan Ag.

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