Yellowhammer strikes gold

AHDB

from theory to field

> “Combining genes that have a different biological function is going to be more durable than combining genes with the same function.”

This season, yellow rust is causing some head scratching in the field as it appears in unexpected places. This only serves to highlight the importance of a major research project looking for more durable yellow rust resistance, alongside continued pathogen population monitoring. *CPM* finds out more.

By Adam Clarke

Researchers have been quietly mining the wheat genome for novel yellow rust resistance and they have possibly struck gold, giving breeders a toolbox of markers that can give new wheat varieties durable defence against the disease.

There are three related rust diseases that affect wheat crops across the globe, including yellow rust, brown rust, and stem rust. All can have a devastating impact on yield given suitable conditions.

The former two are common in the UK, but there is just one — namely yellow rust — that’s a problem every year, with the UK’s temperate maritime climate being perfect for the pathogen’s development.

Fungal diseases like yellow rust can be managed in two ways — by growing a resistant variety, or by treating with a rust-active fungicide where appropriate. Wheat breeders have predominantly been using major “R” genes to build plant resistance to the biotrophic disease, but this type of gene is relatively easy for the pathogen to overcome.

Lesley Boyd, research programme leader and yellow rust specialist at NIAB, says that this happens when a genetic mutation occurs in the yellow rust population, so the plant’s resistance mechanism is no longer triggered when it attacks.

Resistance failures

These mutations happen in dramatic fashion, as growers have seen over several decades. New races are named after the varieties whose resistance genes failed, with names such as Brigadier, Robigus and, most recently, Warrior all on the unfortunate list.

In her 30 years working with wheat/yellow rust interactions, the Holy Grail has been finding genes that offer more durable resistance, preventing these dramatic cliff-edge failures.

“Durable resistance can be described as resistance that has remained effective for a long period of time in a variety that has been widely used across the wheat area,” says Lesley.

There have been several research projects led by NIAB over the years that have aimed to meet grower demand for more durable resistance. One was WAGTAIL, which ran between 2011 and 2015.

Working with breeding partners in the UK, Denmark and Sweden, along with major plant breeding companies, it assembled some 500 different wheat lines popular across northern Europe with the hope of finding resistance to multiple diseases, including yellow rust.

Several genes were found that were contributing to yellow rust resistance and it was thought these genes could be durable, rather than the flash in the pan R-type genes easily bypassed by the pathogen.

This led to a spin off project dubbed Yellowhammer, which looked to confirm the promise of the yellow rust resistance genes discovered in WAGTAIL and add further genetic materials to the selection that plant breeders may be able to utilise.

Casting the net more widely was particularly important at this point due to the massive change in the genetic structure ▸

Lesley Boyd has spent much of her career on the quest to find durable disease resistance and project Yellowhammer may have uncovered how to get there.

So far, project Yellowhammer has unearthed about 20 different genetic markers of interest.

of the yellow rust population when the Warrior race arrived in Europe from Asia, explains Lesley.

"It prompted us to look again at the sources of resistance in UK and northern European wheat breeding material. The pathogen is always changing, and you need to keep a handle on what resistances are effective against the current population.

"For one individual breeding company, that's expensive and requires too much resource, but if they work as a community, assisted by research institutes like NIAB, it's a way of sharing the burden," says Lesley.

So, what work has been done within Yellowhammer? Initially, another 460 lines were screened in the field by the breeders in several countries. These included the UK, Denmark, Sweden, Germany and Northern France, providing diversity in location and pathogen population.

The same group of wheat lines have also been genotyped using the latest technology, so researchers understand the genetic makeup of each and have marked areas of interest for yellow rust resistance on their threads of DNA, she highlights.

Lesley says once you have the markers, you can then see if a particular wheat line containing a marker matches the phenotypic trait of yellow rust resistance in field and glasshouse tests.

Mining the genome

As the full wheat genome has been sequenced, the team at NIAB are utilising this resource, mining deeper into the genome to determine exactly which genes are responsible for the yellow rust resistance and how they work.

This is important because markers are not always precise in the first instance, she adds. The right gene may be a couple of places up or down the chain of DNA, so being as accurate as possible with markers can make the commercial breeding process more efficient.

"For example, the traditional R-type genes used for yellow rust are easily recognisable from patterns in their protein structure. However, this is the type of resistance wheat breeders want to avoid."

Instead, they are looking for what are known as biologically functional genes, for example peroxidases which are responsible for turning hydrogen peroxide into oxygen, and they too have recognisable protein structures that give their function away, explains Lesley.

This reactive oxygen is an antioxidant which in humans is known to fight diseases like cancer, and in plants it helps fight fungal pathogens. "If we have a marker of interest, we can look closer and if we find a potentially biologically functional gene two or three down the chain, we know it may contribute to a resistant phenotype.

"A more accurate marker for that functional gene can then be made, and double checked to see if it expresses itself in the phenotype," explains Lesley.

So far, the project has unearthed about 20 different markers of interest. It's also building a picture of what other biological functions those pieces of genetic material offer and how they are best combined to offer full resistance to yellow rust, she adds.

Lesley and the team at NIAB have recently harvested glasshouse material containing various combinations of genes from the top 20 yellow rust resistance hits identified in Yellowhammer.

These have been infected with yellow rust and the behaviour of the pathogen will be observed in the presence of the different gene combinations at microscopic level, recording how the pathogen grows and feeds within the leaf, and how many spores it produces.

"The hypothesis is that combining genes that have a different biological function and confer resistance in different ways is going to be more durable than combining genes with the same function.

Research into practice

Given the season, where conditions for yellow rust have been ideal and changes in virulence may have occurred, Limagrain cereal pathologist Rachel Goddard is encouraged by the output of the Yellowhammer project.

She says one of the most interesting aspects of being involved in the project has been the screening of older varieties which were released onto the market 30 years ago.

Results have shown that some varieties which were susceptible to older yellow rust races are now resistant to current UK population of yellow rust and could provide some useful genetic material to stack into varieties within Limagrain's breeding programme.

She is also encouraged by the analysis of micro-phenotyping data and mapping of populations for novel sources of resistance, which is ongoing at NIAB, and this will help build more resilient varieties in the future.

"In the data, different genetic loci associated with resistance can change from year to year and location to location, which really underlines how dynamic the yellow rust population is. It shows the benefit of importance of the project's surveillance and monitoring of varieties over several sites and several seasons, as it can throw up some surprises," says Rachel.

Rachel says the micro-phenotyping is addressing a big question that pops up amongst growers and agronomists each year about seedling and adult plant resistance. Sometimes varieties can be susceptible to yellow rust in the autumn and early spring, before adult resistance kicks in. This can lead to a dilemma on whether to treat early or can catch people out when the focus is on septoria control.

It's hoped that markers and more information about the genes responsible for the two types of resistance, like when they become active, will allow breeders to potentially stack both in one variety, she adds.

"The combination of seedling and adult resistance together could potentially make plant resistance more durable. Also, if we know whether varieties have one or the other, we can pass that information on to the grower to help make more informed management decisions in the field," says Rachel.

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Outputs of UKCPVS enable plant breeders to produce varieties that are more resistant against representative isolates present in the UK says Charlotte Nellist

▶ "It's all about providing breeders with as much information as they need about what's present in the material and accurate markers to use now.

"In the future, the research community needs to continue to provide this information and knowledge as the pathogen population changes. That will be of huge value going forward and must stretch beyond the end of Yellowhammer," says Lesley.

Asked how durable the resistance of new generation varieties using the Yellowhammer genes will be, she couldn't provide a definitive answer, replying that there are many variables when genetics are exposed to the environment and pathogen population.

However, she's certain that the material will be more effective than the major R genes used before. "The more knowledge we have the better. Without genetic markers and a sequenced genome, we were blindly selecting based on phenotype and ended up with R genes that would last two or three years.

"Now, breeders will be constantly improving varieties and moving those genes around in different combinations to maintain resistance."

The genetic work and breeding efforts would not be possible without the disease monitoring work carried out by UK Cereal Pathogen Virulence Survey (UKCPVS), led by NIAB.

The ongoing project, funded by AHDB and the Animal and Plant Health Agency (APHA), aims to understand what's happening with pathogen populations in farmers' fields, including yellow and brown rust and wheat and barley powdery mildew.

It is the only extensive survey of its kind in the UK and identifies population changes using its seedling differential tests. These screen a sub-set of pathogen isolates on a range of seedlings with known resistances to each disease.

The risk associated with the change is then identified through screening of a sub-set of isolates in adult plant field trials and AHDB Recommended List or RL Candidate variety seedling trials.

The UKCPVS team are also part of the European project, RustWatch, which monitors yellow, brown and stem rust across Europe, alongside a network of 25 partners.

It aims to develop an early warning system for the three rust species to improve the farming industry's resilience the diseases. This will be achieved by linking rust surveys like UKCPVS with others across Europe.

Micro-phenotyping host resistance to dynamic rust populations and integrated pest management trials across Europe will quickly be able to offer practical advice to growers where necessary.

Charlotte Nellist, NIAB's pathology programme leader in charge of UKCPVS, says that the survey's vital monitoring work identified and supplied the isolates and spores for use in the Yellowhammer project.

"It ensures the most prevalent race at the time is used and the validity of the identified resistance (which will be incorporated into breeding programmes)," she explains.

The genotyping technology so important in Yellowhammer is also being utilised by UKCPVS to understand more about the yellow rust pathogen itself and has allowed plant pathologists to broadly group isolates into genetically similar groups.

"However, we know that within these groups, the isolates harbour different virulence profiles — essentially, they have a different set of genes that are able to overcome their respective resistance gene.

"Last year, we were able to genotype 48 different isolates of wheat yellow rust, allowing us to gather additional information to the supplied sample information," says Charlotte.

She adds that this supplements the seedling differential data and is all combined and used for selecting representative isolates for adult plant trials. This is important with such a complex population, helping to classify isolates and track any changes.

"Outputs of the survey also enable the breeders to produce more resistant varieties against representative isolates from the UK," says Charlotte.

She adds that in time, UKCPVS would like to add genotyping of wheat brown rust and septoria into the survey, given the right funding and research developments, adding the information breeders and growers can utilise.

"We value the time everyone takes to send in samples to the survey and would encourage this to continue.

"All samples are important and enable us to build up the best picture of what's happening to the pathogen populations across the UK. Details of how to get involved can be found on the NIAB website," says Charlotte. ■

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Research roundup

From Theory to Field is part of AHDB's delivery of knowledge exchange on grower-funded research projects. *CPM* would like to thank AHDB for its support and in providing privileged access to staff and others involved in helping put these articles together.
For further info:
AHDB Project 1701165: A multi-locus strategy for durable rust resistance in wheat, in the face of a rapidly changing pathogen landscape (Yellowhammer) is being led by NIAB, with BBSRC as a scientific partner. Industry partners include RAGT Seeds, Limagrain UK, Saaten-Union (including Elsoms Wheat, DSV and LSPB), Lantmannen, SW Seed, Sejet Plant Breeding and Syngenta. The total value of the project is £657,519.
AHDB Project 21120034: UK cereal pathogen virulence survey (UKCPVS) is led by NIAB, in scientific partnership with APHA. The current phase of AHDB and Defra funding from April 2019 totals £800,914.