> *"The goal is to find a sustainable approach to take-all management."*

Research informs integrated control

Technical
Take-all

Control of take-all currently relies on long-standing cultural methods and one seed treatment, but research is hoping to find new measures to compliment these existing tools. *CPM* takes a closer look.

By Rob Jones and Lucy de la Pasture

Little new basic or applied research into the epidemiology or management of the soil-borne cereal pathogen, take-all, has occurred in the UK since the turn of the century. But over the past five years that has changed — a recently published paper from Rothamsted Research shows potential new tools have been identified that can bolster integrated control of the disease.

Take-all is caused by the fungal pathogen *Gaeumannomyces tritici*, and although septoria, rusts and fusarium are often seen as more important, the root disease can have a devastating impact on yield in second and third wheat crops.

According to data from AHDB, half of wheat crops are affected annually, with yield, quality and financial losses ranging between 5% and 20%, depending on situation. In some seasons when conditions favour the disease, a yield loss of up to 50% is a possibility.

As well as these direct consequences, Rothamsted Research expert Javier Palma-Guerrero says that there are also some less publicised "cascading consequences" of take-all that are becoming increasingly important.

Nutrient uptake

Because the pathogen attacks the roots of susceptible cereal crops — such as wheat, barley, triticale and rye — nutrient uptake is reduced. This in turn can lead to increased nutrient run-off and eutrophication of water courses, he highlights.

Where nutrient inputs go unused, this is unnecessarily contributing to greenhouse gas emissions — with synthetic fertiliser one of the worst culprits — and stifling efforts to meet a widely accepted and ambitious target of Net Zero by 2040.

This further highlights the need for a better understanding of the disease and novel management tools for the future, he believes. Javier and the team at Rothamsted are now looking at the three-way interaction between take-all fungi, the plant and the wider soil microbiome.

"The goal is to find a sustainable approach to take-all management. It's all about building knowledge and identifying what's important in pathogen virulence and plant defences against the fungus at a molecular level," he explains.

One of the potentially exciting avenues of the research is further improving the tolerance or resistance of wheat varieties to take-all. Sources of genetic material have been identified in both wild and domesticated relatives, he adds.

As previously reported in *CPM*, work published in 2018, again by Rothamsted, showed that there are differences in how ▸

Because the roots are affected, take-all can lead to reduced nutrient uptake, which in turn may have environmental consequences.

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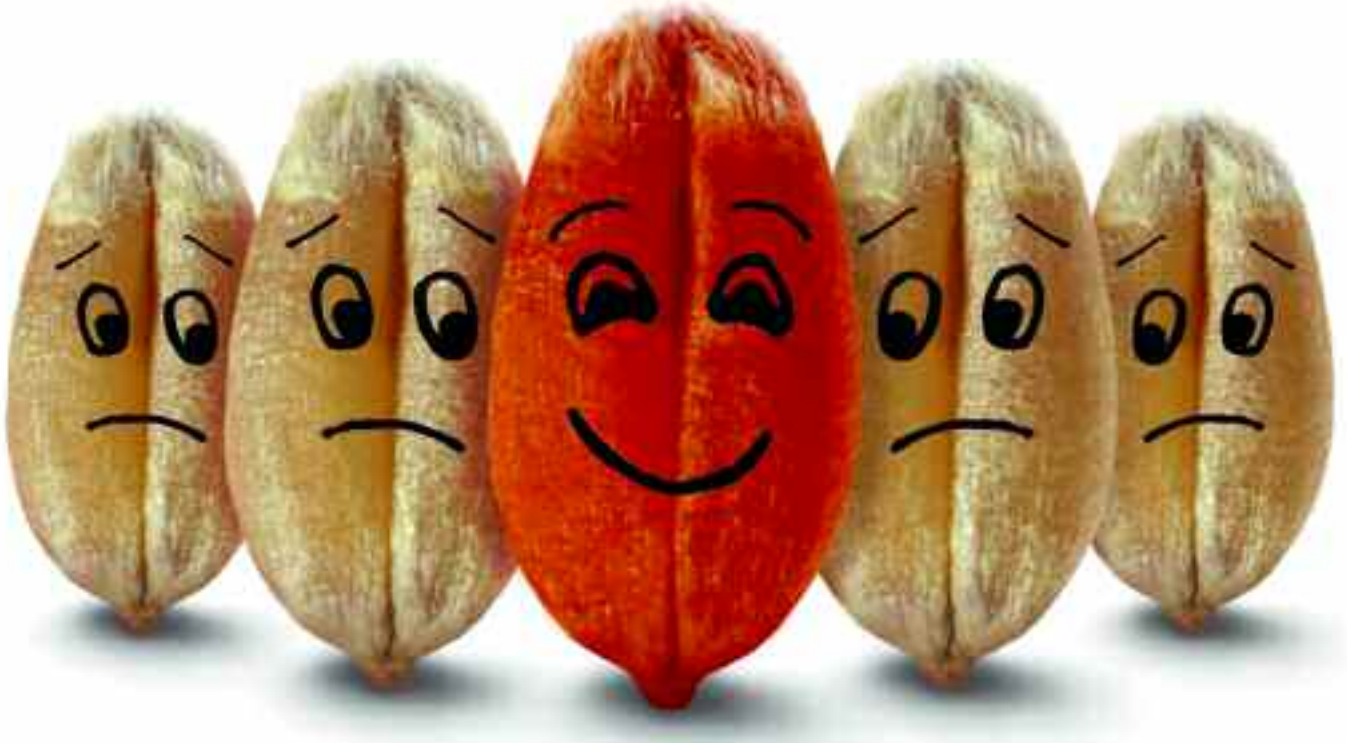

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► modern varieties behave in the presence of take-all, with take-all build-up (TAB) levels lower after some cultivars were grown as a first wheat.

This allows second cereal growers to utilise varieties in the first wheat slot that don't put as much take-all pressure on the following crop, he explains. Building on that, researchers at Rothamsted have identified a possible 'gold mine' of resistance genes in wild wheat relative *Triticum monococcum.*

Mapping genes

They are currently in the process of introducing these genetics into modern wheat lines through introgressive hybridisation — a processes that involves repeated backcrossing — and mapping the genes that express resistance.

It's hoped that these markers will provide breeders with the tools to produce new varieties more tolerant or resistant to take-all in the near future. The group is also investigating the potential of rye as a source of genetic tolerance to take-all.

Rye can be affected by the disease, but some varieties are not, which might be due to an ability to compensate for root damage with new root growth. Identifying which genes are responsible for this phenotype could allow the transfer of the mechanism into wheat for improved tolerance in risky osituations, he explains.

One of the potentially exciting avenues of the research is further improving the tolerance or resistance of wheat varieties to take-all, says Javier Palma-Guerrero.

"We've produced F1 and F2 hybrids so far, so it's very early stages, but the hope is to have more resistant varieties and it looks promising," says Javier.

An area that has been underexplored is the complex interactions of take-all and other fungi and bacteria in the soil and this could provide some interesting take-all controls of the future, he suggests.

This is a particular area of interest for those moving to regenerative agriculture which aims to achieve a healthier and more balanced soil with less room for damaging pathogens.

Research performed in collaboration with the Molecular ►

Some varieties appear to be more susceptible to take-all than others.


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Discovering more about the complex relationships in the root's microbiome will help inform an integrated approach to take-all control.

▸ Microbial Ecology Group at Rothamsted has characterised the bacterial communities surrounding wheat roots and their impact on take-all, improving understanding of the interactions between wheat, the soil microbiome and take-all.

Some bacteria are known to either help or hinder the fungus in the soil and it's been shown that when *Pseudomonas* bacteria are abundant, so is take-all, but when levels are low the disease struggles to get a foothold.

The interaction is not yet fully understood. Some *Pseudomonas* species produce anti-fungal substance 2,4-diacetylphloroglucinol (DAPG), while others produce different chemicals that are yet to be characterised.

Root exudates

Rothamsted scientists have already observed that some varieties result in less take-all build-up and that may be because they are secreting root exudates into the soil microbiome that attract the bacteria that limit the disease.

"That is what we are trying to understand. As well as bacteria, we have also identified naturally occurring fungi that may or may not be having an impact on take-all levels," he adds.

Another promising area for research is the transcriptome — the array of messenger molecules that turn DNA instructions into proteins. The fungus and wheat otranscriptome have both been characterised during the infection process, providing new gene targets for future

Researchers at Rothamsted have identified a possible 'gold mine' of resistance genes in wild wheat relatives.

antifungal development or for improving host resistance.

The available transcriptome data will also allow comparisons with similar disease systems, so as to compare the plant responses between different organs, for example between roots and leaves, and between biological and climate-driven stresses.

In addition, by silencing certain fungal genes, researchers have now been able

Views from the field

Zantra agronomist Chris Bean worked on take-all research as a student in the mid-1970s, but much has changed in crop husbandry and agronomy since then. That's why he's encouraged to see new information being overlayed on to that historic textbook knowledge, which should help improve its management.

He points out that with the advent of neonicotinoid seed dressings, little or no work was done on flea beetle because it was so well controlled, leaving oilseed rape growers exposed once the seed treatments were banned.

Chris draws a parallel with take-all, where control has relied mainly on chemical seed treatments and research has been stymied for a long time.

"25 years down the line, everyone wished they had done more research on flea beetle and it could be the same with take-all," he says. "There's a lot to be understood, such as how and when we cultivate soils, when we put fertiliser on and what type of fertiliser, seed treatment interactions and cover crop interactions. The list goes on."

It's uncertain how climate change will impact on take-all epidemics, but warmer and wetter autumns and winters seen recently may help it thrive and become more threatening to wheat yields, he adds

In regenerative cropping systems Mike Harrington helps his clients adopt cultural methods such as rotation, later drilling, and soil health improvement to help reduce the risk of take-all.

This is partly achieved by a more stable and diverse biological system within the soil, helping to ensure that pathogens such as *G. tritici* are not allowed to become dominant and cause plant health problems.

The work at a molecular level that's being carried out at Rothamsted will help build a better understanding of these observations and improve advice on how soil health and management can aid integrated control strategies, he says.

Even so, Mike says it's difficult to say that take-all will never become an issue in any system, especially where growers favour second wheats and are forced to plant seed in less-than-ideal soil conditions that could hinder rooting.

He adds that growers still have a chemical seed treatment to fall back on, but it's about utilising it intelligently alongside other all-important parts of the system, including varieties and biologicals that may stem from the Rothamsted work.

"In the past we haven't bothered sorting out the root of the problem before using chemicals. As a result, we have the terrible situation of resistance because we've been wedded to that easier approach rather than intelligent management," he concludes.

Chris Bean is happy to see new research taking place which will help update management practices for take-all.

Mike Harrington advocates using intelligent management and all the cultural tools possible and is hopeful the Rothamsted work will produce new biologicals as well as varieties.

Tim Eaton says the prospect of more take-all tolerant varieties in the future would enhance growers' ability to sustainably grow second and third wheats.

to ascertain the function of specific genes within the fungus and how important they are in the infection process.

According to Javier, such studies have previously proven difficult but advances in genetic techniques have opened the door to these new approaches.

"The developments in genome-sequencing techniques and comparative genomics, now make it possible to construct a 'pangenome' for this species, which will contain information from all the different global strains and which genes are found in all strains and which are not.

"Plus, the recent advances in genome-editing tools, like CRISPR-CAS 9, will promote the understanding of the take-all molecular mechanisms of virulence in the near future, which together with virus/host-induced gene silencing and virus-induced over expression of wheat root genes, will allow precise dissection and understanding of the key molecular interactions underlying this disease."

This improved understanding that will stem from the Rothamsted research may lead to biocontrol methods. Examples of these could include seed inoculants to encourage the right organisms in the root zone or being able to produce a particular compound produced by the bacteria or fungi and harness in a crop protection product.

Until these new tools are developed Javier says options for managing take-all remain limited to cultural methods including diverse rotations, trash management, later drilling, first wheatvariety choice and finally a seed treatment.

"Latitude (silthiofam) is the only fungicide seed treatment available that is effective against take-all and although not 100% in terms of control, it helps to protect yield," he adds.

Certis' seed treatment expert Tim Eaton says Latitude is a key part of growers' defences against take-all, particularly as consistently profitable break crops have become harder to find and second wheats become attractive to maximise margins.

However, since fluquinconazole was withdrawn a few years ago, it has been the only means for growers to reduce primary take-all infection where a crop is likely to be at risk.

"It's important not to be too reliant on one active ingredient, so it's great to see investment in basic research that will lead to a range of tools added to our IPM approach to take-all."

He adds that while currently there is no varietal resistance to take-all, Certis have long advocated the first step in control should be choosing a proven robust second wheat variety from the information on suitability included in AHDB's Recommended List.

"The prospect of new research that will enable selection of more take-all tolerant varieties to be taken one step further is hugely positive and will enhance growers' ability to sustainably grow second and third cereals for years to come," says Tim. ■