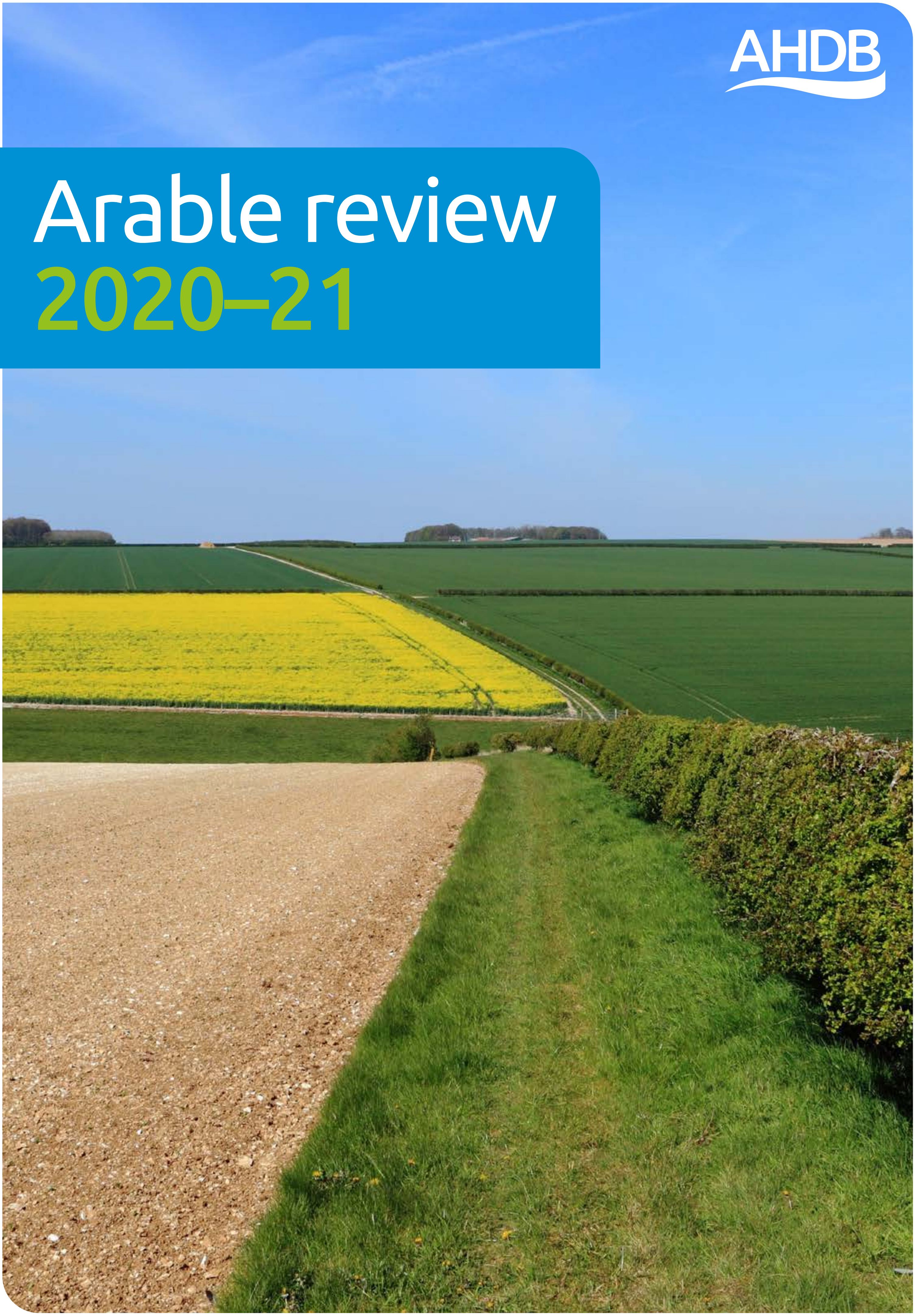
# Arable review 2020–21



# Contents

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# Foreword

**Welcome to our arable research review for 2020-21.**

This publication functions as a summary of research projects for both AHDB Cereals & Oilseeds and AHDB Potatoes. I hope you find it a valuable reference. Not every project is summarised, but you will find a list of current projects on pages 28–31, together with information on our wider technical activity. The review demonstrates the full breadth and depth of the research we commission for the arable sector.

Further information on both our current and completed programmes is on our website. You can search by the topic or project number (provided in brackets), together with details of the PhD studentships and Nuffield Scholarships we support.

The original ambition for the first edition of this publication remains – to help provide a clearer, stronger and more unified resource for the arable sector. As a combined team (AHDB Cereals & Oilseeds and AHDB Potatoes), we deliver much better value for money by joining up similar areas of research and knowledge exchange, while ensuring the levy raised from the individual sectors remains ring-fenced. Some topics will always be sector-specific and these are reflected in the more specialist projects, whereas our work on soils, rotations and so on, is of relevance to all.

We invest a large proportion of the arable levy in the AHDB technical programme. Industry feedback shapes the future research programmes, within the context of the AHDB strategy. This year, the format of Arable Review reflects AHDB's new strategy, which focuses on three core elements – Evidence, Farm Performance, and Market Development. This review focuses in particular on the environment and Integrated Pest Management (IPM) strategies.

While our research reports provide an extremely valuable resource in their own right, there are also many opportunities to see them brought to life through our Farm Excellence programme, which includes Strategic Farms, Monitor Farms, Arable Business Groups, technical events and webinars. I encourage you to get involved with these, wherever you are in the country.

It's also important to mention that we work in collaboration with a long list of industry partners, meaning that levy payers see the value of combined funding and expertise, and less duplication. Common problems require common solutions and we need to move quickly to address new challenges, so you will also see our partnership approach highlighted in this review.

If you would like more information on the full range of our activity, including the many online tools and resources produced from our research, take a look at the AHDB website. All publications can be found at **ahdb.org.uk/knowledge-library** and reports; meeting dates and results from the on-farm demonstrations at our Monitor and Strategic Farms can be found at **ahdb.org.uk/farm-excellence**

**Richard Meredith**
Head of Arable
Knowledge Exchange


Yellow sticky pest trap in cereal crop

# Integrated Pest Management (IPM)

**Paul Neve**
Head of Crop Health & IPM

## Introduction

Limiting the impact of pests, pathogens and weeds on crop yield and quality is a critical aspect of crop management. Pesticides and bioprotectants are important tools enabling pest and disease management, but their availability is increasingly limited by regulation, resistance and slower discovery of new plant protection products. At the same time, government policy discourages use of pesticides and greater adoption of Integrated Pest Management (IPM).

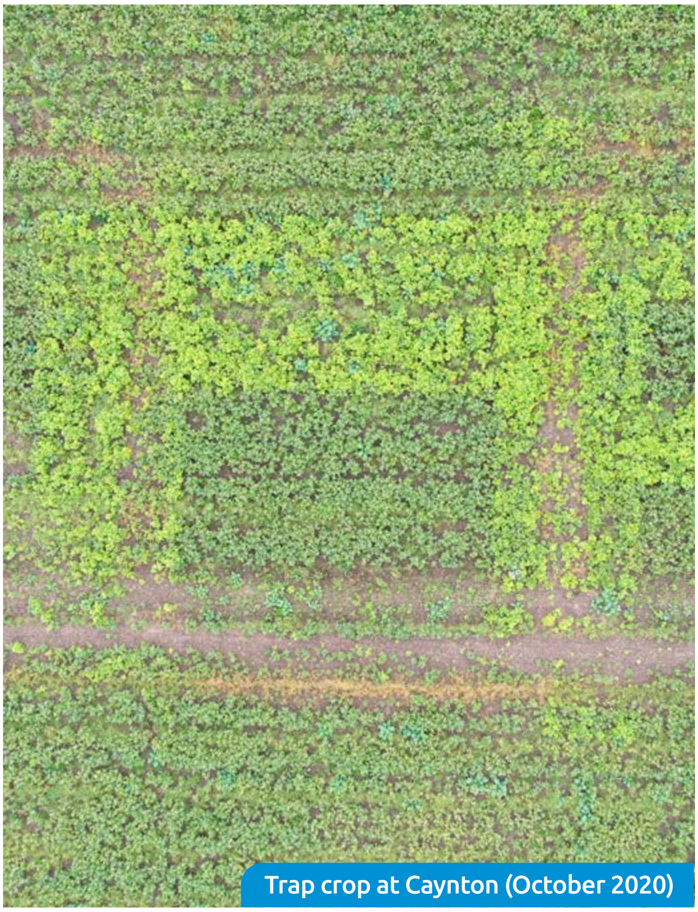
IPM, which includes management of pests, weeds, and diseases, is not a new idea. However, AHDB recognises that the incentive to adopt IPM practices is increasing. We will support levy payers by commissioning research, providing knowledge exchange and communicating new guidance and best practice to make IPM practical, understandable, and making sure those who adopt it are recognised and rewarded.

**We define IPM as a coordinated and planned strategy for the prevention, detection and control of pests, weeds and diseases.**

***Prevention*** means planning activities to reduce the incidence of pest, weed and disease outbreaks. For example, through crop variety choice, crop rotation, enhancement of natural enemies, environmental manipulation, and biosecurity and hygiene measures.

***Detection*** includes monitoring, surveillance and decision-support activities that use the latest sensors, diagnostics and models for better targeted crop protection measures.

We will help the industry use conventional pesticides and bioprotectants, along with other new, emerging or existing genetic or agronomic technologies, to deliver sustainable ***control*** of pests, weeds and diseases that minimise crop losses and damage, maintain productivity and reduce the environmental impact of crop protection.


Trap crop at Caynton (October 2020)

Cabbage stem flea beetle

# Pests

**Charlotte Rowley**
Crop Protection
Scientist – Pests

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Scientist – Pests

Over the next five years, AHDB will focus on the ways in which we can help farmers prevent, detect and control insect pests in their crops. This has never been more important as conventional insecticides become increasingly restricted or ineffective. The following explains how our research supports Integrated Pest Management (IPM) in arable farming, broken down by the key themes of 'prevent', 'detect' and 'control'.

## Prevent

A fundamental part of any IPM programme is reducing the risk to the crop before planting because prevention is better than the cure.

Cabbage stem flea beetle continues to pose serious challenges for farmers. ADAS recently led research into identifying the factors that influence levels of cabbage stem flea beetle damage in a crop by modelling data from over a decade of field trials (PR623). They looked at data for various agronomic and meteorological factors and identified two main risk factors: weather and drill date.

Many farmers are using earlier sowing times to establish the crop before adult migration begins. The research showed that earlier sowing dates were associated with lower adult damage. This makes sense with what we know about the ability of oilseed rape to recover from feeding damage after the four-leaf stage. However, the data also showed that early sowing was associated with higher larval damage, with the risk decreasing in later sown crops. This is likely to be because in early sown crops there is a longer window for egg laying to occur before temperatures drop. The decision-making around sow date varies greatly by farm and, given the importance of establishment, it's recommended that farmers continue to drill when conditions are most suitable rather than by calendar date. However, this finding raises important questions about whether later sowing windows could be an option under some circumstances as a way to reduce larval damage, and, if so, how best to manage such crops.

Outputs from this project will feed into a new phase of research starting this year, led by ADAS and Harper Adams University, shedding light on gaps in our understanding of flea beetle biology, migration and yield impacts. Another part of the project, led by ADAS alongside a host of industry collaborators, will test a number of different strategies to reduce the impact of cabbage stem flea beetle within a network of field trials. This will include trap cropping, companion cropping, establishment methods, nutrient and straw management.

Future years will see the most promising strategies combined, in an attempt to maximise the benefits. This work, in combination with an ongoing PhD project (21120064) investigating the genetic basis for flea beetle resistance in oilseed rape, demonstrates the breadth of research needed to tackle a major pest, where traditional control options are limited.

Cabbage stem flea beetle

A better understanding of a pest's biology is another route to reducing the risk to the crop. In particular, understanding the key species involved, their distribution and the amount of damage they cause. This has been the approach taken with root lesion nematodes (RLN) where soil samples from two hundred potato fields have been assessed as part of a PhD project (11120009) at Harper Adams University. The results will provide a better picture of where the different species occur, while the impacts of different levels of RLN on tuber yield and quality are being studied under controlled conditions.

Important agronomic decisions that farmers and advisors already make, such as cultivation, variety selection and rotations, can also play a huge role in pest prevention. Sometimes, however, there is the opportunity to think a little creatively about how to prevent pest populations from building up in the crop. A new PhD project starting at Harper Adams University this year aims to do just that by investigating varietal differences in the host plant preferences of cereal aphids arriving in autumn.

Preliminary work at the university involving simple choice tests shows some clear differences between modern and heritage cereal varieties, with aphids preferentially landing on the latter. If this can be replicated in the field, this behaviour could be exploited to develop a trap cropping approach, which then forms a target area for biological controls or insecticides to prevent further spread of aphids into the crop. Furthermore, the project will address the reason for differences in host crop preferences, which could pave the way for improved aphid monitoring by incorporating attractants into traps. Despite lots of advances in pest monitoring over the past few decades, spotting aphids in an autumn cereal crop remains a tricky business.

## Detect

Improvements in pest monitoring are not only about improving trapping though. AHDB's Pest Bulletin has a range of forecasting models developed for pests in field crops and now a new report could lead to improved forecasts of wheat bulb fly pressure in cereals. As part of the current Wheat Bulb Fly Survey project (21120003), researchers at ADAS improved the accuracy of an old model that uses weather data to predict the number of eggs laid each year. By using this new approach, combined with information on previous crops, farmers will hopefully be able to make informed assessments of wheat bulb fly risk in time for important decisions about drill date and seed treatments. While the wheat bulb fly survey will continue to run for the next few years to allow for further validation of the models, this new data-driven approach could improve forecasts in the future.

AHDB's Aphid News provides information on aphid migration timing and levels in arable crops every year. Aphid counts come from a network of 14 suction traps – 12 m high towers that suck aphids out of the air as they disperse. Entomologists at Rothamsted Research or SASA sort the trap contents on a weekly basis. They then report numbers of key aphid species via Aphid News.

Similarly, AHDB supports monitoring of aphids in seed potato crops via the aphid monitoring website hosted by Fera. Aphid numbers and the associated virus risk for potatoes are reported from ~100 yellow water traps located in or near seed crops. The host grower or agronomist empties the traps, and samples are sent to Fera for identification.

The main focus is on the aphids that are known to transmit viruses such as Potato Virus Y (PVY) and Potato Virus A (PVA). These are non-persistent viruses and, currently, it's not possible to reliably detect whether aphids are carrying the viruses. In contrast, techniques are available to test whether cereal aphids are carrying Barley Yellow Dwarf Virus (BYDV), which is an example of a persistently transmitted virus that has a longer-term association with the aphid than viruses such as PVY. As a result, it's possible to assess the percentage of cereal aphids that are carrying BYDV, which are caught in suction traps. This has been reported in Aphid News and will be used to support work in our current BYDV project (see Control section).

Potato Aphid

Grey field slug

Tagged slugs tracked with RFID scanner

## Control

Aphid monitoring and how it relates to management decisions is a key feature of AHDB's current BYDV research project on how suction trap catches relate to numbers in crops. The aim is to use the information to feed into decision support systems (DSS) to aid aphid management and reduce insecticide use. The project refreshes previous work in this area, using models of aphid development and virus transmission to improve our understanding. The central aim is to develop a 'risk DSS' and a 'spray DSS' enabling farmers and advisers to better understand virus risk in the early growing stages, to reduce or eliminate insecticide applications without compromising the crop.

In potato crops, the focus is on evaluating alternative options for reducing virus transmission. This includes the use of straw or intercropping with vetch in addition to mineral oils (which are used as plant protection products overseas). The straw is thought to reduce the visual contrast between the ground and crop, resulting in fewer aphids landing on the crop. Intercropping is thought to create a physical barrier between plants and provide 'stylet cleaning' material, whereby aphids landing on the intercrop lose virus particles before moving to a crop plant.

Reductions in the use of plant protection products can also come from improved precision. Molluscicides such as ferric phosphate, for instance, tend to be distributed throughout the crop to control slugs. However, as most farmers will be aware, the slugs themselves tend to occur in patches rather than an even distribution. Therefore, while ferric phosphate is a safe and effective treatment for slugs, application is far from targeted.

Previous AHDB work in this area (SR43) investigated the mechanisms behind slug patch formation using innovative radio frequency identification (RFID) tracking of individual slugs. Now, the same team at Harper Adams University is exploring the potential for soil mapping, to predict slug patch formation by identifying the combinations of soil characteristics associated with such patches. This work could lead to the reliable identification of slug patches within a crop, allowing for reductions in pellet use and opening up the potential for biological solutions in situations where broadscale application is currently too expensive.

Biopesticides can play an important role in IPM programmes, offering several advantages over conventional insecticides. This solution could be effective in the case of cabbage stem flea beetle, where insecticide resistance impedes conventional control methods. This is the subject of a current PhD project (21510042) at Harper Adams University, in which a range of biopesticides are being screened against flea beetle adults and larvae. The work will also look at the effect of combinations of products, and investigate whether certain biopesticides have the potential to make resistant flea beetle populations more susceptible to pyrethroid applications. A better understanding of biopesticides, including usage and compatibility with other strategies, is likely to be an important part of successful IPM programmes in the future.

Cabbage stem flea beetle is not the only pest where insecticide resistance is an issue, however, and with a limited range of active ingredients approved for use in arable crops, there is a risk of further problems developing. This is why AHDB, with support from BBRO, agrochemical and agronomy businesses, continues to monitor for insecticide resistance in a range of crop pests (21510015).

Due to their short generation times, aphids are particularly adept at developing resistance to commonly used insecticides and, therefore, form the focus of the work. Peach-potato aphids are routinely screened against a range of compounds, while pyrethroid resistance is monitored in cereal aphids. For other pests, such as currant-lettuce aphids, potato aphids, willow-carrot aphids and diamond-back moths, tests are carried out where failures of control are suspected. Growers can send samples from treated crops to Rothamsted Research where they can be used to look for evidence of changes in insecticide sensitivity. This is an exciting time for pest research as AHDB makes IPM a central theme of the 5-year strategy. Be sure to keep an eye out for the results from these projects and opportunities to get involved.


Hand-weeded plot at SPot West


Black-grass in winter wheat

# Weeds

**Joe Martin**
Crop Protection Senior Scientist – Weeds

The loss of actives and increased resistance to available products mean growers continue to face challenges managing weeds. Research across the arable sector identifies mechanisms to prevent, detect and control weeds as part of an IPM strategy.

## Preventing herbicide resistance in bromes

Increased resistance to herbicides in black-grass highlighted the importance of managing the risk in other grass. The aims and objectives of this project (21120059) assess distribution and presence of brome populations to help us understand how herbicide resistance may develop.

The four-year project used a UK-wide survey of farmers and agronomists to determine the extent of the five main brome species in the UK. It also identified areas where infestations are spreading. Glasshouse experiments and field surveys investigated herbicide resistance evolution and determined herbicide susceptibility in key brome species. The project aimed to develop an integrated weed management system to help maintain and improve herbicide control, while reducing the risk of resistance build-up evolving.

Outcomes include:

- Brome resistance to acetolactate synthase (ALS) inhibitors confirmed
- Applying ALS herbicides is most effective at growth stages (GS) 12–13
- Further results will be available in 2021 when the project concludes. Researchers are carrying out field work to investigate and further quantify the findings

IPM will continue to play a key role for growers. The weed review (P1807258) published in 2019 (**ahdb.org.uk/weedreview**) provides information on a range of different tools, both currently available and under development. This includes technology that helps growers improve their precision when applying actives. Looking back on previous research was an important part of the review to prevent duplication. It also meant reviewing weed management practices that didn’t use conventional chemistry. Additional funding was provided to create a database of research sources, to prevent them becoming lost in the future.

Precision application could become increasingly important. The EyeSpot project, funded by AHDB, aimed to develop a tool to help apply herbicides to the leaves of a crop, to control weeds in field vegetables. Researchers from the University of Reading and Concurrent Solutions developed a prototype, which they demonstrated during summer 2019. They found that:

- Applications to the leaf of the crop satisfactorily controlled weeds in both glasshouse and field trials
- Glufosinate-ammonium may be an effective alternative to glyphosate
- There was a reduction in herbicide inputs by 97% for cabbages and 74% for leeks when using the new technology
- In 80% of cases, researchers predicted that using precision technology to apply herbicides to the leaves of a crop was more profitable and cost-effective than conventional spraying

## Managing the resistance risk to retain long-term effectiveness of glyphosate for grass-weed control in UK crop rotations

Ending this year, a 5-year project (21120023) will provide practical management guidelines for farmers and agronomists to help reduce the risk of grass-weeds becoming resistant to glyphosate.

The main grass-weeds tested were black-grass and Italian rye-grass at two key risk periods of glyphosate application: pre-drilling and post-emergence. A goal of the project was to quantify the need for repeat applications on stubble or pre-drilling, and determine ways to mitigate risk using alternative management practices, such as cultivation.

The project also looked at the need for glyphosate post-emergence, such as between crop rows, and ways to determine a resistance status.

Key messages coming out of the research, are:

- The ideal time to apply glyphosate is GS12-13
- Glyphosate dose >540 g ai/ha is critical
- The temperature at the time of application has an significant effect on the efficacy of glyphosate
- Cultivation in stale seedbed is essential
- A minimum of two timings for stale seedbed reduces the risk of resistance developing in survivors

## Desiccation control in potatoes

At AHDB there are several projects running, including work on potato desiccation, to help growers gain a better understanding of the available desiccation products and optimise their use. The loss of diquat means potato growers must seek alternatives for crop desiccation.

The objectives of the desiccation trials (11120038) in 2019, were:

- To produce guidance on the best desiccant, combination of desiccants or non-chemical control (haulm killing) in indeterminate varieties and seed crops
- To create synergy with other existing or previous AHDB projects (e.g. determinacy, cultivation and nitrogen utilisation) in optimising the N rate for the remaining desiccants, to achieve rapid haulm death and minimise time to skin set
- To demonstrate research in Strategic Potato (SPot) Farm programmes involving N nutrition
- To develop best practice guidance on timing, to avoid internal defects with desiccation
- To identify whether certain desiccation practices lead to increased severity of blemishing diseases post-storage

### Some of the recommendations – 2019 results

Differences in the rate of foliage desiccation between treatments did not correlate well with skin set.

The rate of foliage desiccation did not correlate well with skin set, meaning growers cannot use the former as a guide for the latter.

Early- to mid-morning application of PPO gave the chemical maximum time to kill cells. The application timing for Spotlight/Gozai can be more crucial later in the season when it is cooler.

Skin set is faster in dry soils. Most trial sites contained crops desiccated with wet soil in 2019. As a result, researchers expected slower skin set. This meant the timing of the last irrigation (particularly salad crops) is important and farmers should aim to stop irrigation for seven days prior to desiccation for best skin set results.

The results also showed that the type of active used affected the rate of skin set.

There was a 2-4-day delay in skin set when using Spotlight/Gozai compared with using Reglone, flail, haulm-pulling or Saltex. Therefore, harvest schedules will need to take account of this.

In crops or at sites experiencing difficulty achieving skin set owing to active green canopies at desiccation, 10% less nitrogen than the amount recommended in AHDB's Nutrient Management Guide (RB209) may advance canopy senescence.

Mechanical methods stop tuber bulking immediately, but there is little evidence that 'passive bulking' (whereby the tuber continues to grow despite initial treatment with a desiccant) differs across chemical treatments.

It is important to kill all leaves and prevent regrowth to control tuber blight or virus infection in seed. The defoliation method, chemical or timing have little effect on vascular browning, stem-end necrosis or stolon adhesion, or on rotting or skin blemishing diseases, either pre- or post-storage.

The work on crop desiccation will continue this year to test the theory that reducing N can advance canopy death.

Product stewardship and understanding weed resistance to available products are an important part of AHDB's work. More information can be found on the AHDB website.

Desiccation and re-growth

Yellow rust in wheat

Brown rust in wheat

# Diseases

**Cathryn Lambourne**
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**Catherine Harries**
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Scientist – Diseases

## Prevent

Key to sustainable disease control, using a crop with genetic resistance reduces risk and fungicide use. Unreliable varietal resistance, however, can be worse than using a variety with no disease resistance at all.

## Yellow rust in wheat

Resistance to yellow rust in available varieties of wheat has not always been reliable during recent growing seasons. This is because many varieties with this trait on the AHDB Recommended Lists (RL) depend on a single major gene. If pathogen populations change, this gene can be overcome. The UK yellow rust population is extremely dynamic, creating constant change in varietal resistance. While modifications to the RL aim to keep the listings up to date, it's not possible to predict changes to the pathogen.

The Yellowhammer project (P1701165) aims to breed wheat varieties with durable resistance to yellow rust. To do this, researchers are looking for the most effective combinations of adult plant resistance genes providing resistance against multiple races of yellow rust. Trials are taking place in the UK and Northern Europe. They will expose wheat varieties to diverse pathogen populations across successive growing seasons. The results so far show the diversity in both time and space in the yellow rust population.

## Blackleg in potatoes

Scientists at the James Hutton Institute, together with AHDB and other partner organisations, are working to understand the interactions between pathogen *Pectobacterium atrosepticum* (Pba) and free-living nematodes (FLN) in the development of Blackleg. Biotechnology and Biological Research Council (BBSRC) has provided £17m of research funding to tackle bacterial diseases in UK crops. One of the research projects is Building a Decision Support Tool for Blackleg Disease (DeS-BL). The project focuses on vectors and transmission; current management practices and investigating the rhizosphere. Researchers hope the work will have a major impact in the potato industry by encouraging growers to adopt new practices. It uses the data to describe trends and drivers of Pba incidence to produce predictive models for decision support tools. As partners in the project, AHDB transfers research into practice through the Strategic Farm programme.

Blackleg

## Detect

Working alongside the Yellowhammer project, the United Kingdom Cereal Pathogen Virulence Survey (UKCPVS) continues to monitor the UK populations of yellow and brown rust. Vital to understanding the current dynamic rust populations, the results are presented at an annual stakeholder meeting in March. Results from the 2018 and 2019 seasons show that the 'red' genetic group continues to dominate the population, but this group can infect a wide range of varieties. UKCPVS trials show which varieties these new races infect, and this helps breeders understand which resistance genes are going to be most useful in future breeding programmes.

The UKCPVS relies on growers, agronomists and trial operators to send in their infected leaf samples. Sampling instructions are available at **niab.com**

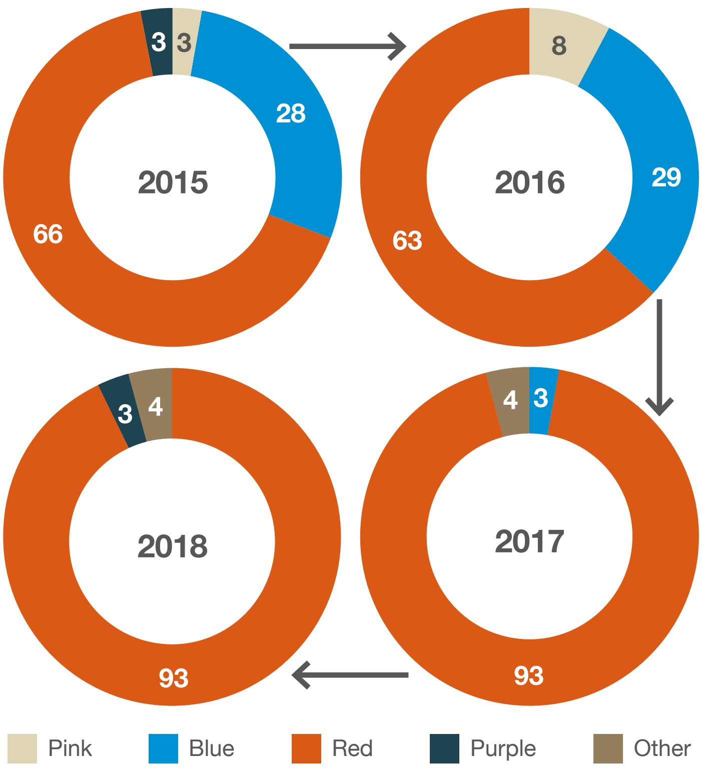
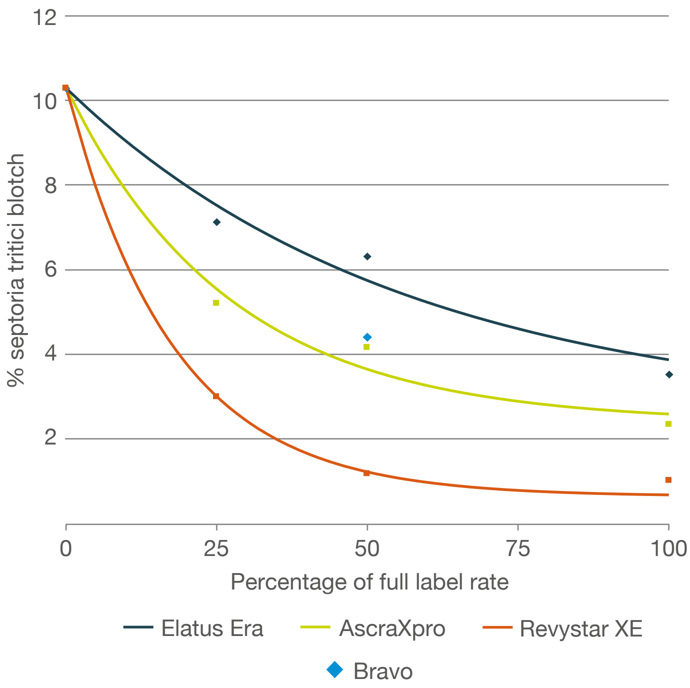



Figure 1. Change in yellow rust genetic groups

At the start of the potato blight season, samples began arriving in the James Hutton Institute labs from blight scouts around the UK. The labs are now able to receive both fresh leaf and FTA cards. Received samples will be confirmed as blight, and genotyped so that growers and agronomists can monitor crops for the presence of any fungicide resistant isolates; this forms the 'detect' component of this project. At the end of the season, fungicide sensitivity testing will be carried out on a geographically spread set of isolates, to ensure there are no shifts in genotype response to key active ingredients, helping farmers with the control of outbreaks. A full report on the fungicide testing for the 2019 season is available. We are keen to encourage new scouts to join the project, to increase the geographical spread of samples. You can sign up by visiting **blight.ahdb.org.uk/BlightReport**

## Control

With a dwindling portfolio of plant protection products available to UK growers, the independent information provided by AHDB on fungicide performance and resistance is vital to inform product choice and preserve efficacy. Working with the fungicide resistance action group (FRAG) and researchers, AHDB keeps its finger on the pulse of the susceptibility of the *Zymoseptoria tritici* (septoria tritici blotch of wheat) and *Phytophthora infestans* (late blight of potatoes) populations to new and established fungicides.



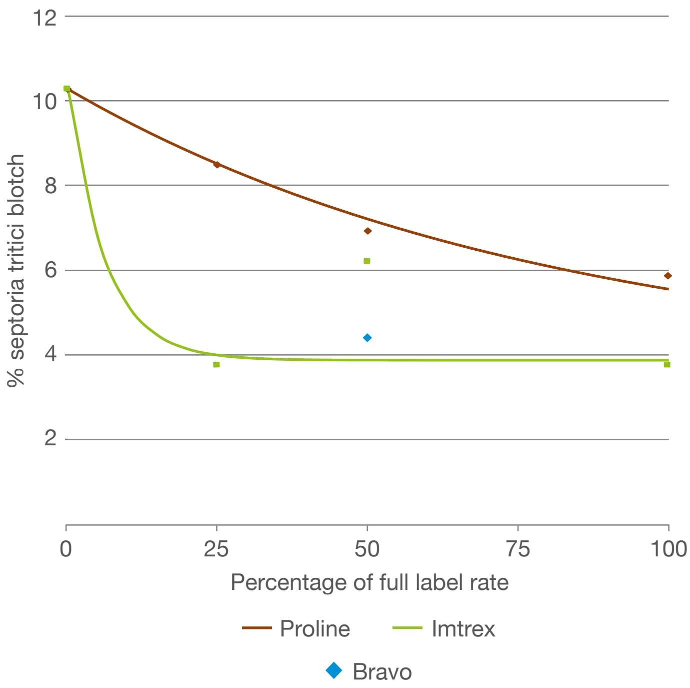




Figure 2. Example of fungicide performance curve for septoria tritici control in 2019

We use information from this monitoring to inform the results from the Fungicide Performance work for wheat, barley and oilseed rape, and identify areas where more work may be required. We use results from the monitoring in research projects, looking at techniques to slow the development of resistance. Recent projects looking at fungicide resistance in wheat and oilseed rape consider the cost to the grower of fungicide resistance strategies, to ensure they are practical and viable on farm.

There have been no major changes to Fungicide Resistance Action Group (FRAG) guidance as a result of these projects so far. Growers can manage resistance, by:

- Using all practical, non-chemical control options such as varietal resistance and delayed drilling
- Minimising the number of applications
- Using the minimum dose required, to effectively control the target disease
- Including a multisite fungicide, where available, in both the early- and late-season sprays
- Making full use of effective fungicides with different modes of action in alternate sprays or mixtures. Where possible, make sure the mixture is balanced (i.e. use mixing partners at doses that give similar efficacy and persistence)

This year, we have also joined the ADAS-led Blight Fungicide Resistance Management project. The aim of the project is to determine, and rank, effective strategies to reduce the likelihood of resistant strains of the pathogen developing. Experiments undertaken at two sites will address the following objectives:

Determine appropriate strategies to slow resistant pathogens developing, using alternation, mixtures and multisite fungicides in multi-spray programmes

Test the effect of adjusting dose on the pathogen under field conditions (IPM)

Produce a set of evidence-based guidelines outlining best practice and cost-effectiveness for the industry

The results will help to inform AHDB Potatoes, the Fungicide Resistance Action Group and other stakeholders to implement best practice

Late blight on potato leaf

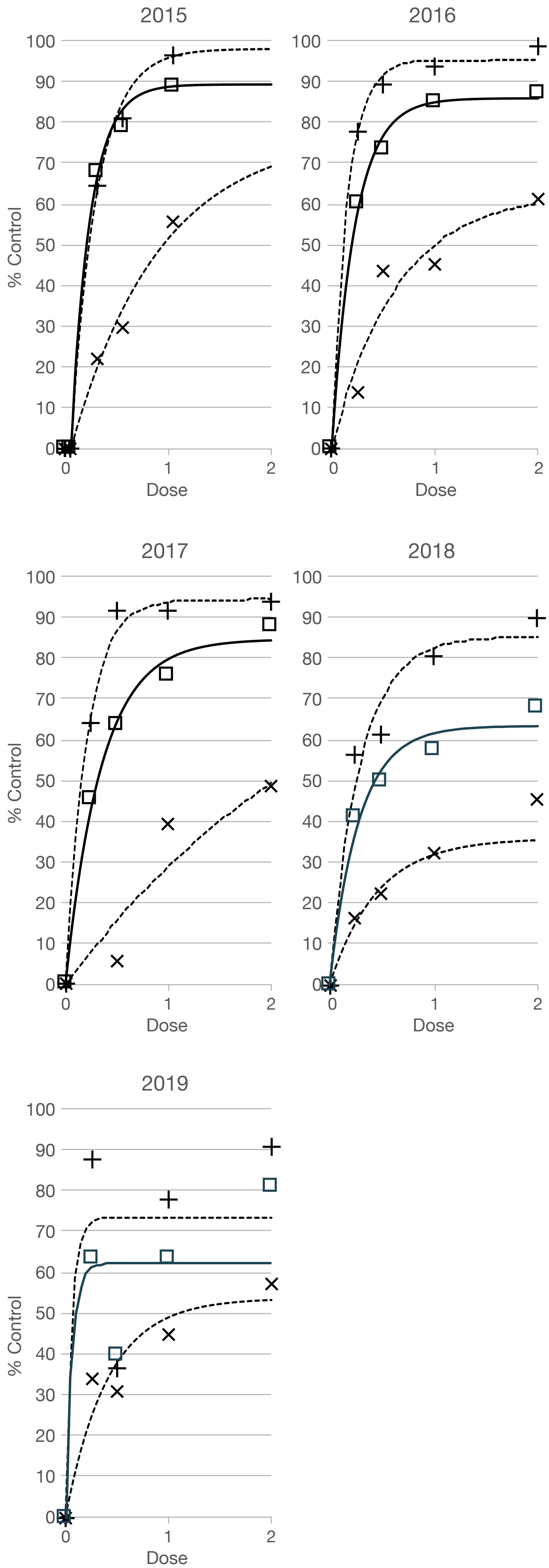



Figure 3. Change in resistance over time: SDHI efficacy from 2015–2019

# Environment

**Jon Foot**
Head of Environment
& Resource Management

## Introduction

The industry has already taken many significant and positive steps to becoming more environmentally friendly. At the start of 2019, AHDB started work to develop a 5-year environment programme to equip farmers with evidence to support their environment strategies.

The programme is in line with the NFU's Net Zero Farming's 2040 Goals, which set an ambitious and broad framework for agriculture to contribute to the UK's goal of net zero carbon emissions by 2050.

We're developing a proposal to provide carbon footprint audits on up to 50 farm businesses that are part of the AHDB Farm Excellence Programme. The audits will use a recognised tool that is readily available and free to use.

Our work will not recommend any particular tool to conduct a carbon footprint audit. This is because we're aware many farmers already have equipment that suits their business needs. Instead, we are developing a pilot service that will help growers use the results from their audit to create a plan to reduce carbon emissions. The pilot will recommend that growers conduct annual audits to track the benefits.

We are in the early stages of a project to develop a system that helps collate and benchmark environmental data across all farming sectors. We also hope that growers can use the data to access the government's new ELMS payments.

The sector has an important role to play in protecting and enhancing our rural landscapes. Focusing on carbon emissions only can result in unintended consequences,or poor environmental outcomes by moving emissions to countries where other environmental standards may be lower. We need to look holistically across a range of issues, to ensure we find the optimum outcomes for farmers, society and the environment.

Prior to the COVID-19 pandemic, we saw public concerns about the environment moving up the list of issues affecting what and how they buy. More than half of the UK public were more worried about climate change in the past 12 months, with two-thirds suggesting we should limit air travel and move to electric cars sooner.

In a world where environmental and climate change concerns continue to be at the top of customers' concerns, we are aware that we need to help UK agriculture meet the demand for safe, affordable and sustainable food. This is why the new AHDB 5-year strategy will have the environment and net zero embedded within all the elements of work we deliver. We believe that good business returns and good environmental performance are not mutually exclusive.

Floral margin

GREATSOILS

# Soils

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Resource Management Scientist – Soils

**Alice Sin**
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Soils are the foundation of arable farming, supporting crop growth and providing key functions such as nutrient cycling, water regulation and carbon storage, as well as supporting biodiversity above and below ground.

Managing soils to improve productivity and maintain wider ecosystem services in the long term can involve a variety of different approaches, considering local soil type, regional climate, cropping choice, inputs and field management. AHDB research and knowledge exchange activity provide practical tools and methods for measuring and monitoring the condition and health of soils, for farmers, growers and their agronomists – whatever the production system.

## Measure to manage

How do you know if your soil management approach is optimising conditions for crop growth and environmental benefit in your fields? A rotational approach to assessing soils can help provide regular insight on whether management choices are on the right track, and indicate where further attention might be required.

The AHDB-BBRO Soil Biology and Soil Health Partnership (91140002) is a 5-year programme of research and knowledge exchange (2017–2021), aiming to develop and validate thresholds for a range of physical, chemical and biological indicators of soil health. These indicators are brought together as a soil health 'scorecard', using a traffic-light system to show whether results fall in the expected range for UK soils and climatic regions.

Results flagging red (outside of established threshold values) mean further investigation is needed to determine the cause of that particular result and may inform future soil management decisions. Amber results highlight where additional – perhaps more frequent – monitoring would be beneficial, whereas green results indicate no action is currently needed. Farmers' knowledge of their own fields is important for interpretation of the results and can also help inform where progress can be made in both the short- and long-term to improve soil health.

Table 1 shows an example of the soil health scorecard from one of the Soil Biology and Soil Health Partnership long-term research sites (Gleadthorpe: loamy sand), being used to test organic material additions on soil and crop quality.

**Table 1. Example soil health scorecard for Gleadthorpe experimental site**

| Attribute* | Control | Broiler litter (20yrs) | Cattle FYM (8yrs) | Cattle slurry (8yrs) | Green compost (13yrs) |
|---|---|---|---|---|---|
| SOM (%)** | 1.9 | 2.1 | 2.7 | 2.2 | 2.8 |
| pH ** | 6.8 | 6.6 | 7.9 | 7.4 | 7.5 |
| Ext. P (mg/l)** | 42 | 71 | 53 | 46 | 48 |
| Ext. K (mg/l)** | 96 | 192 | 326 | 155 | 177 |
| Ext. Mg (mg/l) | 32 | 60 | 75 | 57 | 62 |
| VESS score | 3 | 2 | 2 | 2 | 2 |
| Earthworms (Number/pit) | 0 | 1 | 0 | 1 | 0 |
| PMN (mg/kg)** | 12 | 26 | 31 | 36 | 35 |

Investigate   Monitor   No action needed

*SOM: Soil Organic Matter – comparison to 'typical' levels for the soil type & climate; Partnership project 2 **ahdb.org.uk/greatsoils**

Ext. P, K & Mg: Extractable Phosphorus, Potassium and Magnesium; See 'The Nutrient Management Guide-RB209' for specific crop advice, **ahdb.org.uk/nutrient-management-guide-rb209**

VESS: Visual Evaluation of Soil Structure – limiting layer score; **sruc.ac.uk/info/120625/visual_evaluation_of_soil_structure**

Earthworms: total number of adults and juveniles; >8/pit = 'active' population for arable or ley/arable soils; Partnership project 2 **ahdb.org.uk/greatsoils**

PMN: Potentially mineralisable nitrogen – comparison to 'typical' levels for UK soils; Partnership project 11 **ahdb.org.uk/greatsoils**

**Attributes that showed a statistically significant difference between treatments (P<0.05)

The results show that organic material applications can significantly increase soil organic matter (SOM) contents on light textured soils, particularly bulky materials such as farmyard manure (FYM) and green compost. These materials also provide valuable nutrients such as nitrogen (N), phosphorus (P), potassium (K) and sulphur (S), although repeated annual applications can result in high levels of P. The visual evaluation of soil structure (VESS) scores showed some evidence of structural degradation (capping and compaction) where soil organic matter was low on the control treatment. Earthworm numbers indicated low/depleted levels of biological activity across all treatments, which reflects the low organic matter content of the light soil texture and plough-based method of crop establishment. However, there was evidence that potentially mineralisable nitrogen (PMN: an indicator of the size of the microbial community involved in the mineralisation of organic nitrogen) was higher on the manure treatments than the fertiliser-only control.

On-farm monitoring of soil health as part of the partnership is also underway, using a suite of soil health indicators that are ready for uptake. This includes: VESS, pH, nutrient analysis (extractable P, K, and magnesium (Mg)), soil organic matter (% loss on ignition) and earthworm counts. Eight farmer groups across the UK are using the soil health scorecard approach in their own fields, providing feedback on ease of use and interpretation. Building on recent research results, additional tests such as $CO_2$ burst and PMN are likely to be included as biological indicators for on-farm evaluation of the scorecard in 2020.

Farmers in the AHDB Farm Excellence network have also used the scorecard approach to baseline soils on their own farms, as part of the Monitor Farm and Strategic Farm programmes. Being able to measure and record specific soils' information for different fields can highlight where different management may have had an impact

## Choosing an option that is right for your soils

General principles for improving soil health include reducing intensity of cultivation, increasing cropping diversity, and the use of organic amendments. Of course, there is scope for a variety of practical options to meet these over-arching principles, and different approaches will need to be adapted to suit specific soil types and conditions.

### Improving soil structure and reducing compaction

In terms of cultivations, the AHDB Arable Soil Management guide highlights a range of options for combinable cropping and potatoes, providing details on key points to consider, as well as pros and cons of different systems. Further to the information in the guide, there is an associated tool to help assess where a change in management approach might be beneficial. This is available at **ahdb.org.uk/arablesoils**

Looking at soil under stubble

As part of the AHDB Rotations Partnership (91140001), a tool to assess compaction risk caused by agricultural machinery is under development for soil types found in the UK. This can help users identify the most beneficial traffic systems for preventing soil compaction. The tool is available at **terranimo.uk** Recent developments include the option to simulate the risk of soil compaction for multiple wheels, and visualisation of the stress across the wheels for each axle.

## Increasing diversity and organic inputs

One of the principles of managing healthy soils is to increase diversity, whether that is below or above ground. Growing cover crops is one way of doing this. Seasonal variation means that much research on soils requires several years of repeated trials in different locations and rainfall regions. The Rotations Partnership (2016–2021) is gathering information from on-farm trials on the effects of different cover crops and the use of organic amendments, particularly for rotations that include potatoes. Results to date highlight the importance of looking at these effects over several seasons, with greater yield benefits occurring in some years compared with others.

Running concurrently with the experimental trials is the collection of grower survey data on past cropping, land use and management practices. This encompasses a wide range of soils, climatic conditions and rotation types. Up to now, approximately 70 crop surveys have been completed. Analysis has shown that, on average, the use of cover crops increased the yield of potatoes.

Similarly, the 21 on-farm comparisons showed that use of a cover crop resulted in a statistically significant yield increase of potatoes of about 3 t/ha. In both the survey and farm comparison data, the benefit of using organic amendments was smaller and non-significant. Economic analysis of both data sets showed the increase in yield for potato crops outweighs the cost of establishing, managing and destroying a cover crop.

For combinable crops, the recently completed Maxi-Cover crop project highlighted the need to consider the economics of using cover crops across the whole rotation, not just in a single season of use. The final report includes a simple template to help record the costs and benefits of cover crops ahead of combinable crops. For further information, see **ahdb.org.uk/cover-crops**

The additional benefits of certain cover crop species are the subject of a current PhD studentship (21140024). This project focuses on understanding whether cover crops can increase populations of beneficial arbuscular mycorrhizal fungi (AMF) and how these carry over into the following cash crop. Some plant species, such as brassicas, are non-mycorrhizal. The project investigates the impact of including species such as radish in a mixture, alongside mycorrhizal species, such as oats and vetch. As well as root colonisation by AMF, the project assesses the impact on crop growth and yield. Findings from this research will help inform the future choice of cover crop species, to enhance populations of beneficial soil organisms throughout the crop rotation.

## Precision farming technologies to enhance rotations

Precision farming technologies and imaging systems can provide growers, agronomists and land managers with a ‘toolbox’ to help them manage soil resources more effectively. The Rotations Partnership uses techniques such as electromagnetic conductance (EMI) scans of soil, maps of variation in potato yield and plough draft to improve our understanding of some of the causes of variation in crop yield and quality. Novel spectroscopic techniques will be explored to establish the chemical composition and quality of organic matter. As well as the spatial distribution of soil porosity using both high resolution RGB light and multispectral imaging (Figure 4).

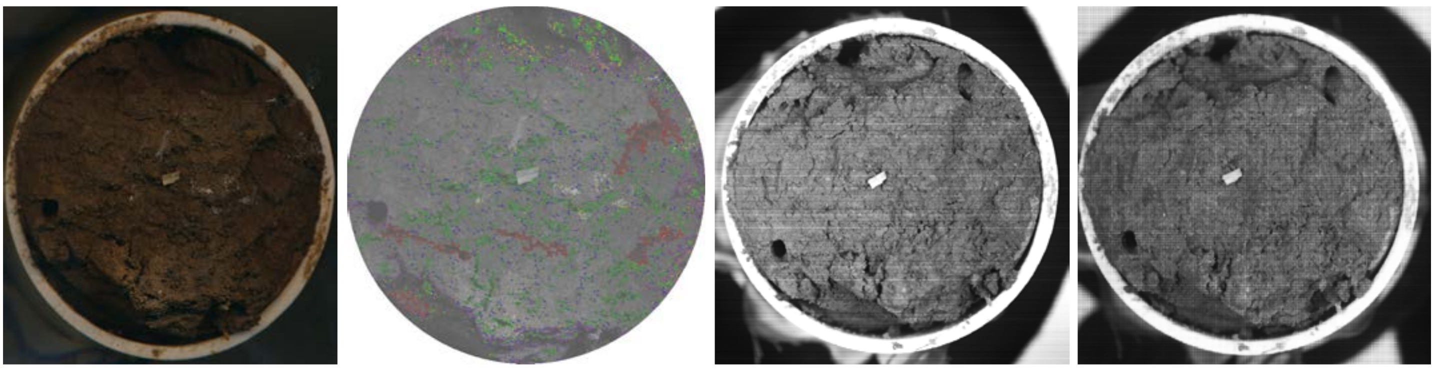

Figure 4. Soil core imaging for porosity (original core, pore distribution and multispectral imaging)

## Soil biology drives functioning

The Soil Biology and Soil Health Partnership aims to improve on-farm understanding of soil biology and the key role that biodiversity plays in soil functioning. The work includes research into an extensive range of indicators at long-term experimental sites investigating the drivers of soil biology. These include organic material inputs that 'feed the soil'; tillage approaches and drainage status that impact the physical soil environment; and pH and fertiliser inputs that can alter the soil chemistry.

Biological indicators being measured include earthworms, mesofauna, nematodes and microorganisms (DNA community analysis and microbial activity). While some of these biological indicators are readily accessible, e.g. earthworm counts, many are still in their infancy in terms of validation and interpretation. Mesofauna and nematode communities have been recorded using microscopy at one of the long-term sites (Craibstone, Figure 5), creating a unique picture of the soil biology associated with the cropping rotation there. For example, crop type – but not pH – was found to influence soil mesofauna communities. Similar studies at other long-term sites will contribute to the wider evaluation of soil biological indicators. However, microscopy is a time-consuming task, and molecular-based techniques to measure and monitor biological communities, including soilborne plant pathogens, are also being explored.

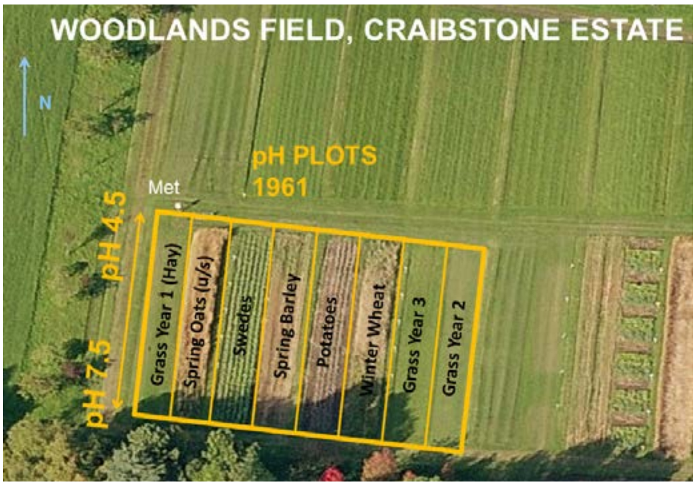


Figure 5. Long-term experimental site at Woodlands Field, Craibstone Estate, investigating the effect of crop rotation and pH

## Shared knowledge and experience

Within AHDB's GREATsoils programme, farmers and growers are working together with research scientists and industry stakeholders to share their knowledge and experience, providing insight and feedback on what is practical and useful, as well as hosting on-farm trials for several projects. To find out more about the GREATsoils programme, visit our website: **ahdb.org.uk/greatsoils**

# Nutrient management

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## Changes for phosphorus management in 2020 revision of RB209

A recent review of strategies for phosphorus (P) management in cereals (RR93) brought research into practice. The review brought together evidence from three AHDB co-funded projects spanning 10 years. The results prompted changes in phosphorus recommendations for arable agriculture. Chief among these changes is an improvement in grain offtake information. New evidence shows lower levels of 6.5 kg $P_2O_5$ per tonne are removed in harvested grain. Alongside this, the new guidance encourages soil and grain analysis for nutrients. It also sets out a new protocol to help growers sample grain for analysis and interpret the results. Further information is provided in RB209.

As a result of these changes in P recommendations, farmers and growers can critically analyse the P content of their grain and make comparisons with their soil tests, improving a farmer's P strategy. Most laboratories carry out grain analysis, and several already offer the service for just over £30 per sample.

You can find these changes in the 2020 revision of RB209, available at **ahdb.org.uk/RB209**

## High yield and grain protein in milling wheat – are the two mutually exclusive?

Research on milling wheat (21140040) runs parallel with spring barley trials (21140038) and explores the effect of nitrogen (N) and sulphur (S) rates and timings required to achieve optimum grain quality and milling specifications. The key factors known to affect protein content and milling quality in wheat are variety, nitrogen rate and timing, nitrogen product, application of sulphur and location within the rotation. Lower protein content is also associated with increasing starch production.

Tests on modern high-yielding Recommended List (RL) varieties will measure grain quality (grain protein and specific weight) in response to N fertiliser application rate and timing. These tests will take into account various soil types and growing environments. They comprise three milling wheat varieties sown during autumn 2019 (KWS Zyatt (Group 1), KWS Siskin (Group 2) and Skyfall (Group 1)).

The project will evaluate the grain quality (primarily grain protein and specific weight) of these varieties under varying N and S timings and rates, as well as their effects on elasticity and baking performance relating to protein quality. Researchers will also evaluate the effect of S on the production of asparagine, a precursor of acrylamide.

### Asparagine and baking rheology results 2019

In general, weather during harvest impacts gluten structure and strength. The south-east of the country, which has lower rainfall, generally resulted in improved quality. However, compared with the 2018 season, which was an exceptional growing season due to very dry conditions, the 2019 season had generally seen lower gluten strength and resulted in poorer crumb structure.

The preliminary results show no correlation between either varieties or nitrogen or sulphur treatments in baking quality. Gluten strength was also lower than expected, in the range of 1.8–2.2. Gluten strength was measured by using R/E ratio. The R/E ratio of gluten affects dough structure, typical R/E values are usually around 1.8–2.2. This was due to exceptionally dry late spring and summer 2019.

### Sulphur and asparagine results 2019

The results indicated a range of concentrations in the grain ranging from 1.85 to 5.44 mmol/kg. However, there was no clear trend that sulphur application was substantially reducing asparagine concentrations in the grain. Trials will be repeated this year to see if any trends become apparent.

## Could we improve malt specifications in spring barley?

The area of spring barley grown in the UK has steadily increased since 2015. It is likely to increase further as farmers use the crop to control black-grass, and as an alternative for oilseed rape.

Malting premiums can be substantial and achieving them is often the difference between profit and loss, but it can be difficult to achieve grain quality targets reliably. Spring barley was traditionally grown on light land, but is now expanding to heavy land too, which is likely to affect the strategies to achieve various optimum N targets in grain. Some modern varieties yield 12% more than some traditional varieties and may require more N to achieve potential yield. It is a challenge to find the optimum nitrogen rate, as growers do not want to exceed thresholds but yield may be compromised by suboptimal rates.

In 2018, research began to address these issues (21140038), and aims to quantify the effect of the rate and timing of N applied to the soil and S fertiliser on grain N% (proportion of grain nitrogen), with a view to developing guidelines for achieving grain N% targets without yield penalty. These trials involve the testing of modern, high-yielding spring barley varieties: Concerto, Laureate, Planet and KSW Irina.

Results from the first two years of trials highlighted the importance of some seedbed N in a dry season.

Experiments conducted so far indicate that, for standard yields above 5.5 t/ha, the N requirement is increased. The results also show that a reduction of 35 kg N/ha is needed to reduce grain N by 0.1%. Sulphur significantly increased yield at one of eight sites, but there has been no consistent effect of N timing/rate treatments or sulphur treatments on malting quality.

A review of literature of published research found that high ratio of (soil N supply + Fertiliser N) to yield correlates positively with grain N%.

The review also indicated that when N applications are split, the first application should be delayed or reduced where the soil N supply and risk of lodging are high.

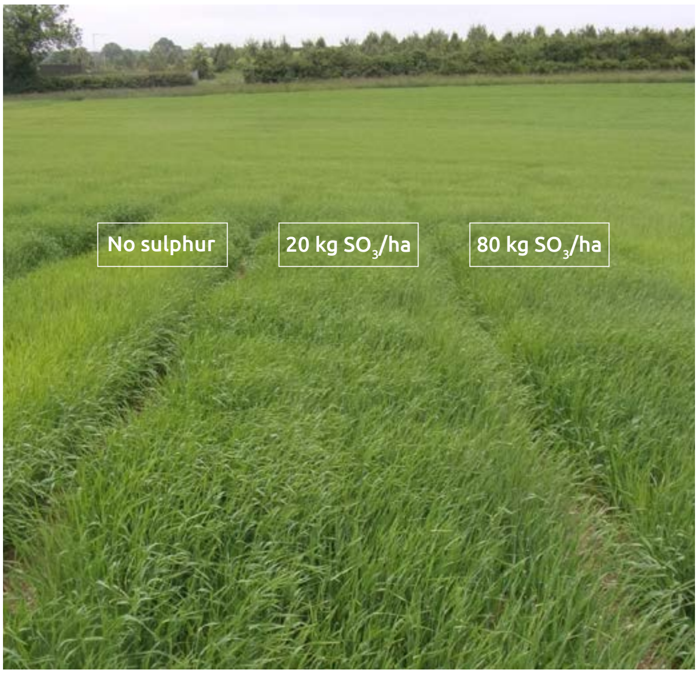


Figure 6. Norfolk experimental site 2018 (spring barley)

## Are oats being fed enough nutrients?

Trials are taking place in England, Scotland and Ireland (21140039) looking at both nitrogen rate and nitrogen timing with sulphur in oats to optimise yield and quality. In addition to this project, Teagasc is carrying out similar parallel experiments on the rate and timing of N, with common treatments over three seasons. They will make the data available to the project.

The nitrogen rate trials analyses three varieties (Mascani, RGT Southwark and Penrose), each grown with six different rates of N, ranging from zero to a superoptimal amount. Each variety and rate combination is replicated three times in a split-plot design.

The experiments looking at different timings of N include the same three varieties used in the experiments looking at the rate of N. In the former experiment, the varieties receive treatments of N at five different timings and one treatment without sulphur fertiliser. Treatments range from N applied before growth stage (GS) 30, to a late timing regime, with the last split at GS37 or GS38.

All but one of treatments in experiments looking at N timing have a standard sulphur treatment of 25–50 kg $SO_3$/ha. One treatment has zero S fertiliser to assess the effect of S. Some sites with a medium to high risk of S deficiency were chosen, based on the S deficiency risk table in AHDB's Nutrient Management Guide (RB209).

Measurements in all N rate, N timing and S experiments also include soil mineral N (readily available forms of nitrogen in the soil) and extractable soil S for each site, tissue malate-sulphur and tissue N:S ratio in early leaves (zero S treatment), yield and lodging. Grain samples from each plot are then sent to Institute of Biological, Environmental & Rural Sciences (IBERS) for grain quality analyses.

### Results from harvest 2019

Data analysed from 2019 trials examined economic optimum N rates, the best N timings and the benefit of S on winter oats (Herefordshire and Nottinghamshire) and spring oats (South East Scotland and East Anglia). A dry spring and wet June affected tillering and caused lodging at both winter oat trial sites. This led to low optimum N rates less than 100 kg N/ha).

Trials investigating the impact of N application timing, compared RB209 timings to applying the majority of the application early; the majority late (including up to GS39); and an even split. The results of the 2019 trial showed that the RB209 timing had higher yields, but the difference between treatments was not statistically significant. There were significant effects of variety on the response and timing trials independently, but no significant interactions between variety and both N rate and N timing. On the light soil site in Nottinghamshire, foregoing applications of S appeared detrimental to yield, although differences weren't significant.

For the spring oat trials, the dry spring in Cambridgeshire led to low yields (less than 6 t/ha) and low optimum N rates less than 100 kg N/ha). The Scottish trial produced relatively high yields and high optima more than 160 kg N/ha). This could be due to better growing conditions compared with those in Eastern England. The timing experiments showed that applying all of the nitrogen in the seedbed led to the highest yields, which contrasts with results found in the literature review. As in the winter oat trials, sulphur had no significant effect on yield.

Grain quality traits of samples from the 2019 trials were tested. Consistent with previous work, kernel content, hullability and screenings increased and thousand grain weight (TGW) and specific weight decreased in response to increasing N in both winter and spring oats. There were clear variety-specific effects and an interaction between N rate and variety for winter oats. Results from the N timing experiments suggested that, for winter oats, early N applications were associated with higher specific weight and kernel content. There were no clear timing effects found for spring oats.

## Can we predict grain protein content earlier, to guide nitrogen management in winter milling wheat?

Hill Court Farm Research is working on a concept to predict grain protein content during late stem extension – GS 37 (flag leaf just visible) to 39 (flag leaf blade all visible). Accurate predications would help target N applications for protein more effectively. Critically, it would help farmers decide whether to continue with a milling wheat strategy or to adopt a lower cost feed wheat strategy instead.

Initial work, in conjunction with CF Fertilisers, revealed the potential of this approach in the 2018/2019 season. This project will continue to test and refine the concept during the 2019/20 and 2020/21 growing seasons. Specifically, Hill Court Farm Research will collect and analyse soil and plant tissue samples from two experimental milling wheat sites, and ensure synergy with AHDB project 21140040 (nitrogen and sulphur management in winter wheat).

## Digging the HS2 data to see the fertility trends in English soils

During the construction of the High Speed 2 (HS2) rail link, over 800 soil samples were taken (2016–19) along the whole length (London to Birmingham, Birmingham to Crewe, and Birmingham to Leeds).

These samples fall into five main areas.

1. Southern: London clay, Chalk, Clay-with-flints (200 samples).
2. Clay Vales: Including Gault, Oxford clays, Liassic clays and limestone (150 samples).
3. Midlands: Pebbly drift, Triassic (red), sandstones, siltstones and clays (150 samples).
4. Nottingham to Leeds: Carboniferous clays, siltstones and sandstones (150 samples).
5. Staffordshire and Cheshire: Glacial Till, Triassic clays and sandstones (120 samples).

A fundamental principle assumed in RB209 is that if nutrients are managed in the topsoil, the subsoil takes care of itself. However, it is important not to overlook the role of the upper subsoil. For example, the upper subsoil contributes a significant supply of potassium (K) to crops. As a result, it is possible for the soils with the same topsoil K index to provide sufficient amounts of this nutrient in some crop situations, while there is risk deficiency in others.

This work will conduct statistical analyses, to:

1. Establish the soil or land use factors that lead to differences in pH, P, K and Mg in the topsoil.
2. Identify the soil or land use factors that affect the relationship between pH, P, K, Mg and organic matter levels in the upper subsoil and topsoil.

This work will establish the potential to exploit the large soil database to inform revisions of RB209. In particular, the work will look at the topsoil, the subsoil and the relationship between them.

Sulphur deficiency in potato crops

## What is the risk of sulphur deficiency in potato crops?

Researchers are investigating the risk of sulphur (S) deficiency for potato crops. In this case, the work aims to specify the conditions under which applications of S to the potato crop can be economically justified. Currently, about one-quarter of the potato crop in Great Britain receives an S application.

However, in the recent review and revision of the potato section of AHDB's Nutrient Management Guide (RB209), a lack of experimental data was found relating to S nutrition of the UK potato crop. The most recent UK data, which were published in Scotland in the mid-1980s, were used to formulate the recommendation for 25 kg $SO_3$/ha (10 kg S/ha) when S deficiency was 'expected'.

Previous UK field studies investigated the effects of N and S application on tuber sugar and amino acid concentrations and on acrylamide-forming potential.

Trial data were inconclusive, but suggested that S applications might help reduce acrylamide formation in crops given excessive N. This current project (11140048) aims to establish an appropriate S application rate in S-deficient circumstances, as well as the effect of S application on the accumulation of acrylamide precursors in cooked potato products.

## Improving nitrogen recommendations in potatoes

Understanding the determinacy group of potato varieties is essential to understanding the appropriate N application rate for a given season length and soil N supply. Current N recommendations in AHDB's Nutrient Management Guide (RB209) are based on determinacy groupings of varieties, although only a few varieties are grouped based on multiple N response trials.

## What is determinacy and how can it help?

Determinate varieties may stop leaf production after they have initiated the first flower, while indeterminate varieties may continue to produce leaves and flowers. Typically, very determinate varieties need twice the amount of N as very indeterminate ones, but calculating the determinacy group of a variety currently requires years of time-consuming and expensive field-testing. This can mean that during the initial commercialisation of new varieties, the recommended N rate is estimated incorrectly, leading to increased production costs, yield loss, poor crop quality and increased wastage.

Research led by the National Institute of Agricultural Botany at Cambridge University Farm (NIAB CUF; 11140044), completed March 2020, set out to produce simple objective measurements to reliably allocate varieties to determinacy groups without extensive field experimentation. These measurements include integrated ground cover, main-axis above ground leaves and harvest index at about 55 days after emergence.

The field experiments demonstrated that counting the number of leaves on a main axis of potato plant is a reliable indicator of the determinacy, and is suitable for use where seed stocks of a new variety are limited. A step-by-step protocol for assigning determinacy groups is now available (**ahdb.org.uk/knowledge-library/in-field-method-for-assigning-nitrogen-group-determinacy-in-potatoes**). This new protocol will help in establishing and updating determinacy groups, incorporated in the Nutrient Management Guide Section 5 Potatoes.

## Further information

Further research updates and resources from the AHDB Crop Nutrient Management R&D and KE programme can be found at **ahdb.org.uk/RB209** The Nutrient Management Guide (RB209) is also available as an app for Android and iOS.

# Grain quality

**Dhan Bhandari**
Cereal Product Quality
Senior Scientist

Various environmental factors can affect the quality and safety of cereals. These include climatic factors such as heat and water stress during grain development and maturation. They also include local soil conditions. The lack of stability of protein content and quality in commercial varieties, particularly in view of the increased climatic variation associated with climate change, are of serious concern to wheat breeders, farmers, millers and bakers. AHDB has recently invested in research projects to address these challenges.

A PhD on the environmental effect of grain protein (21130058) investigates how the amount and properties of gluten proteins in the wheat grain, the major determinants of processing quality of flour are affected. The studentship will exploit genetic variation in the grain content to develop genetic markers, enabling plant breeders to develop improved, new varieties for increased stability. Experimental lines of wheat will be analysed for high grain protein content, high stability traits and baking quality, using replicate field trials carried out in three environments. The successful outcome of the project would have beneficial environmental impacts by allowing farmers to better target and reduce applications of late nitrogen fertiliser.

The water absorption (WA) of wheat flour affects dough and bread-making performance. WA is widely estimated by the baseline prediction model of the Farrand equation (*WA = %starch damage + %protein + %flour moisture*). While millers modify the milling procedure to achieve the required level of WA, they reported difficulties in making such adjustments with UK-grown wheat in certain years.

WA was lower than expected in 2010, 2013, 2015 and 2017, which resulted in millers increasing the use of imported wheat. The precise causes for these seasonal variations were not fully understood. A three-year project (21130025) analysed trial samples grown in years that exhibited typical WA (2016 and 2018) and atypically low WA (2013 and 2017) to identify factors, including starch, protein and fibre composition that affect WA levels. Statistical modelling showed that the inclusion of two fibre fractions, water-extractable arabinoxylan and β-glucan, improved the prediction of WA by the baseline Farrand equation.

Comparison of lines grown with 100 kg N/ha and 200 kg N/ha showed no effects beyond those related to grain protein content (and were, therefore, allowed for in the baseline equation). The results show that variation in the content of fibre components may account for variation in WA between cultivars and between samples grown in different environments.

Nitrogen (N) is a major input that determines crop yield and also grain quality in wheat. It is required for the synthesis of proteins such as gluten. Because of the high protein content required for bread making (13%), the requirement for N applied to wheats may be above the optimum required for yield, by up to 50 kg N/ha. N fertiliser is a major cost for farmers, with high carbon and environmental footprints. Therefore, this project focused on identifying and characterising types of wheat with good bread-making quality at low grain protein content.

The 4-year project funded by AHDB and BBSRC (21130005) aimed to develop new varieties of wheat to allow the use of lower protein content for bread making. Trials of 30 genetically different wheat varieties were grown on six sites for 3 years, with 2 levels of N fertilisation: 150 kgN/ha (low) and 250 kgN/ha (conventional). Figure 7 shows the seasonal variations in yield and grain N content. The bread-making performances were determined by six commercial partners.

Results showed that five varieties performed well at both high and low N: Crusoe and Gallant (UK), Rumor and Nelson (German varieties bred for high quality at low grain protein) and Genius (Danish). Two cultivars performed better when grown at low N than at high N: Skyfall (UK) and Mv Lucilla (Hungarian high-protein bread making). Hence, modern cultivars, which have been selected for performance in high-input systems, could also perform well under low N inputs. It was concluded that good bread-making performance at low N fertiliser resulted from two factors: efficient translocation of N into the grain and increased proportions of glutenin in gluten, which resulted in greater dough elasticity. Breeding programmes should, therefore, focus on increasing the efficiency of N use combined with high gluten protein elasticity. Stability to environmental factors is also key.

A project at the University of Nottingham (21130024) is looking at ways to optimise and enhance fertility in cereal crops. Researchers are working on identifying ways to control fertilisation for breeding and hybrid development, which is key to sustainably achieving high yields in wheat and barley.

Genetically crossing two varieties increases yield (hybrid vigour), but it is challenging, due to the need to avoid self-fertilisation. Therefore, mechanisms that control fertility in a reversible manner are needed. There is also a requirement to ensure effective pollination; this relies on high levels of viable pollen for cross-pollination and is resilient to environmental stress.

This BBSRC LINK Project will provide a greater understanding of pollen development in cereals by developing switchable systems for the control of fertility, but also by identifying traits for enhanced pollen production and viability, particularly under environmental stress. The study is also determining the environmental stability of fertility control mechanisms under different temperatures and light intensities in barley and wheat. So far, the work identified conserved genes involved in pollen development in wheat and barley. This information is being used to generate genetic lines with altered fertility and to develop approaches to control their fertility based on environment. This will be of direct benefit to plant breeders and farmers.

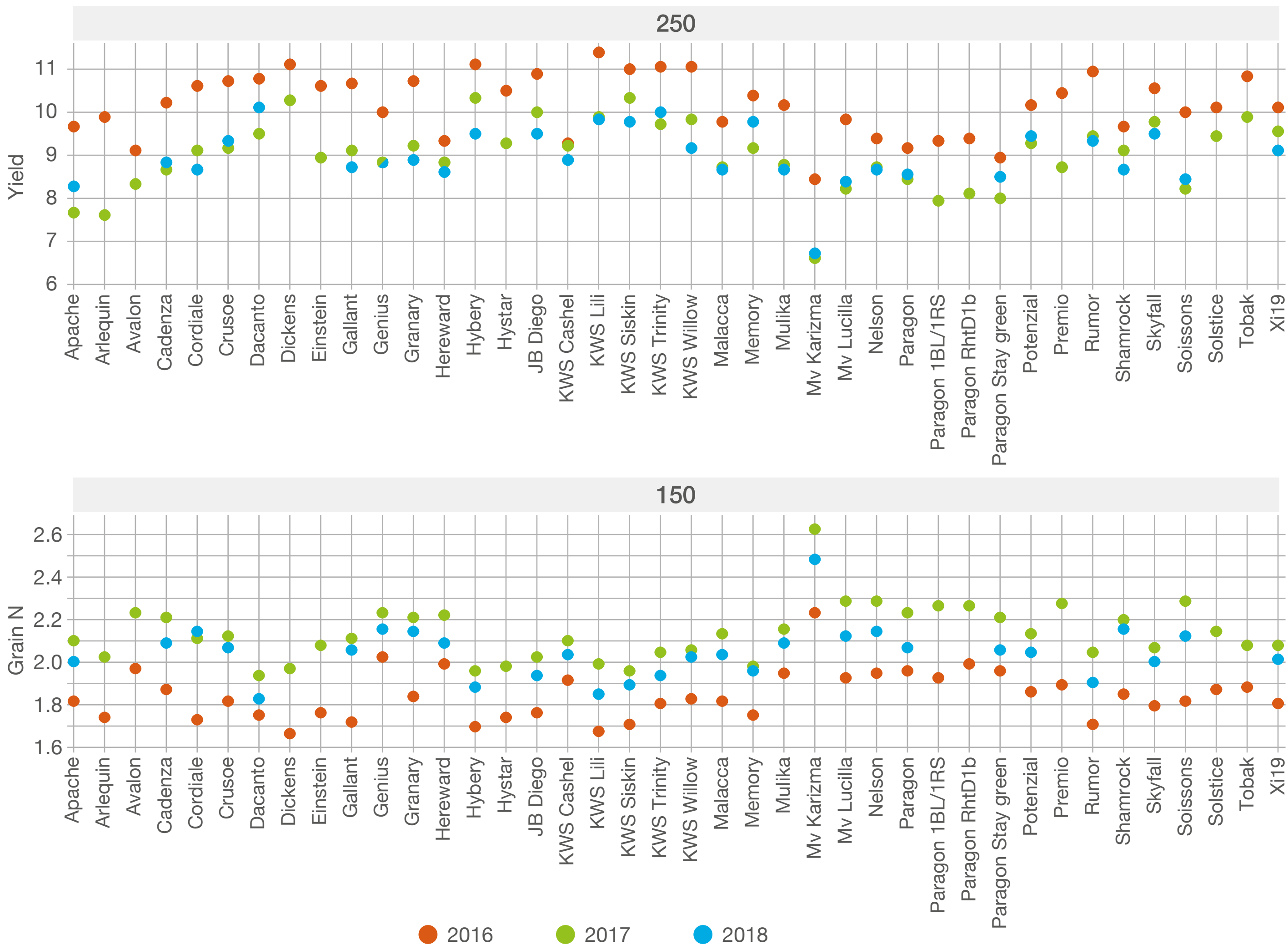


Figure 7. Seasonal variations in grain N and yield 2016–2018

# Potato storage

**Laura Bouvet**
Knowledge & Innovation Facilitator – Crop Storage Research

With the loss of approval of CIPC on 8 January 2020, the potato industry has lost the major active for sprout control over the past 70 years. Alternatives available are not like-for-like replacements and growers need to adopt an integrated approach to storage management, making the best use of all available tools. AHDB is supporting the industry by investing in the latest knowledge and research findings to inform storage decision-making post-CIPC.

## It starts with variety traits

Potato varieties differ in many traits, including dormancy and propensity to low-temperature sweetening, which have the potential to extend or reduce the storage period and the reliance on sprout suppressants.

Dormancy is the period during which tubers show no sprout growth. Sutton Bridge Crop Storage Research (SBCSR) has been generating relative dormancy data for up to 40 varieties representative of the different end markets for potatoes (11910058). Varieties have been grown at two Strategic Potato (SPot) Farms; SPot Farm West, Shropshire, and Spot Farm East, Lincolnshire (part of AHDB's Farm Excellence network), and tubers have then been stored at 15°C. Data from two years of trials shows dormancies range from 160 to 260 days from tuber initiation, demonstrating a considerable range of 100 days from the shortest to the longest dormant variety. This data will feature in the variety selection tool, soon to be available to levy payers.

In addition to dormancy, varieties also differ in their response to cold temperature and ethylene exposure, two factors that are of particular relevance to the processing sector, where an 8–10 °C temperature range is frequently used to produce the best fry colour. SBCSR has been assessing the influence of ethylene and cold temperature on the processing quality of crisping and frying varieties (11910060). The first year of trials suggests a range of sensitivities to each of the treatments. Interestingly, for a subset of crisping and frying varieties, commercially acceptable levels of fry and crisp colour under a temperature regime of 6 °C during storage were achieved, suggesting that cooler temperatures can help to significantly reduce sprout suppressant inputs.

## In the field: Optimisation of maleic hydrazide as a sprout suppressant

Maleic Hydrazide (MH) is applied to the growing crop as a foliar spray to control potato volunteers and to inhibit sprouting. It provides good levels of sprout control as a stand-alone treatment and in combination with other sprout suppressants. The level of efficacy, however, is reliant on how much is taken up by the plant and translocated to the tubers, making MH application a crucial part of the sprout control equation.

Timing of application, together with environmental conditions, such as the weather, at the time of application can have a significant impact on levels of uptake from the leaves and movement into the tubers. Some of these conditions are being tested in field trials hosted at SPot Farm North and SPot Farm West. SBCSR then assesses the tubers for storage (11140056).

AHDB is supporting trials looking at how best to reach an effective MH residue threshold in tubers. Researchers are investigating application timing in relation to plant development and environmental conditions, such as the weather. They will assess treatments at trials hosted at SPot Farm East and SPot Farm West and SBCSR (11140056). This work is now in its second year.


The 2019 AHDB review of MH as a sprout suppressant indicated that a target level of about 12 mg/kg may be required. This figure is backed up by initial data from the AHDB trials (Figure 8). Timing of application will continue to be investigated and, in addition, other agronomy aspects are being explored, including the effect of dose rates and irrigation management.

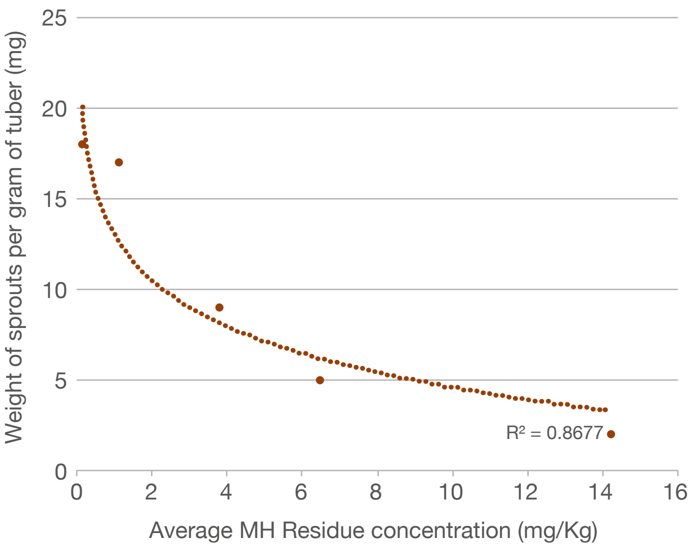


Figure 8. Effect of MH residue concentration on weight of sprouts after storage for *c*.150 days at 9°C

## Sprout suppressant alternatives to CIPC

### Processing sector

The non-renewal of CIPC is a particular hit to the processing sector. Crisping and frying potatoes are usually stored at warm temperatures (6–12°C) to meet commercial fry colour standards. However, as these temperatures are conducive to sprouting, efficient sprout suppression is crucial.

The efficacy of alternative sprout suppressants in stand-alone and combination treatments is being explored (11140043) (Table 2).

Table 2. Processing storage trials summary

| | |
|---|---|
| Varieties | Innovator, Maris Piper, Perfomer, Royal, VR808 |
| Sprout suppressants tested (stand-alone & combination) | Maleic hydrazide (MH), spearmint oil, ethylene, 1–4 dimethylnaphthalene (DMN), chlorpropham (CIPC) |
| Storage conditions & sampling regime | 9°C stores; sampling at 3-, 6- and 9-month intervals |
| Assessments | Sprouting and frying colour |

In 2018–19 trials, DMN was the most effective of all treatments in controlling sprouting. Ethylene and spearmint oil responses were more variable. MH had an important effect on sprout growth as a stand-alone treatment when residues present in sufficient levels. MH, in combination with other sprout suppressants, provided a more effective sprout control than either treatment alone. Fry colour and quality were kept to commercially acceptable standards and were not significantly affected by the different treatments. Ethylene is often reported to cause darkening in colour of tubers, something that was observed in the trials. However, its effects were transient and negligible. Sprout length data from the third year (2019–20) of trials so far is showing the same trends as previous years (Figure 9).

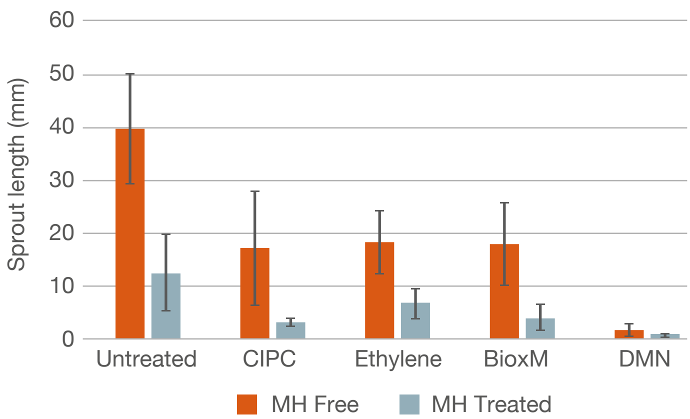


Figure 9. Average sprout length of varieties assessed at 30 weeks of storage under different sprout suppressants regimes

A study at SBCSR in collaboration with the Potato Processors' Association specifically looked at the use of spearmint oil (BIOX-M) on a range of 12 crisping varieties (11910061). This confirmed the importance of MH as a basis of any programme of treatments. It also highlighted the challenges presented by long-term storage of varieties without MH at a temperature of 9 °C. Results for this treatment combination were mixed, with the most successful sprout control achieved in the earlier sprouting assessment (late February).

### Fresh pack sector

An effective sprout control strategy for short- to mid-term storage for the fresh market is storing at lower temperatures using refrigeration. However, this strategy is sometimes not adequate, particularly in under-performing 'overhead throw' stores, where there has often been a reliance on CIPC. This project (111910057) mirrors research trials on alternative sprout suppressants for the processing markets, using fresh pack varieties and temperatures. Similarly, treatments were evaluated as stand-alone or combination treatments (Table 3).

Table 3. Fresh market storage trials summary

| | |
|---|---|
| Varieties | King Edward, Maris Piper, Melody, Nectar |
| Sprout suppressants treatments (stand-alone & combination) | Maleic hydrazide (MH), spearmint oil (BIOX-M), orange oil, ethylene, 1–4 dimethylnaphthalene (DMN), chlorpropham (CIPC) |
| Storage conditions & sampling regime | 4.5°C stores; sampling at 3-, 6- and 9-month intervals |
| Assessments | Sprouting and pre-pack outturn |

In the first year of trials (2018–19), DMN and spearmint oil were both effective at controlling sprouting for all varieties and, in the absence of other treatments, over 9 months of storage. MH provided good sprout control as a stand-alone treatment. When tested in combination with other suppressants, it was more effective than any individual treatment on its own. It also provided some control during shelf life, after store unloading, even after 9 months storage. DMN provided some control during shelf life. Ethylene and orange oil treatments provided some control on shorter dormant varieties and, in combination with MH, could provide acceptable results for pre-pack storage.

## What next for sprout control in the UK?

The latest research on sprout control demonstrates that the various options available to growers have their limitation when used in isolation. In the future, sprout suppression strategies will use a range of different approaches; for instance, combining actives with natural characteristics such as dormancy. Tests showed DMN to be the most effective alternative to CIPC. However, at the time of writing, it is not registered for use as a sprout suppressant in the UK.

The concentration levels of all current alternatives to CIPC must be maintained or replenished during storage. This requires a careful approach to managing the store environment, to prevent excess loss of these chemicals, particularly in leaky stores. Storage trials at SBCSR have shown that these risks can be somewhat mitigated by using MH in combination with other sprout suppressants, and also by making use of variety traits such as long dormancy and cold temperature tolerance. There are viable options for growers to reduce their reliance on the more volatile sprout suppressants, while maintaining commercial standards of sprout growth and quality for the different end markets.

## Consequences of volatile alternatives: $CO_2$ management in processing stores

For DMN, spearmint and orange oil treatments, it is recommended that stores are closed for at least 48 hours after application. However, carbon dioxide ($CO_2$) will build up in the store during this extended store closure.

SBCSR is undertaking trials to measure the impact of this $CO_2$ build-up on the fry quality of processing varieties (11911062, Table 4). This body of work will help inform growers and approval holders how best to manage this build-up and mitigate any impact on quality.

Table 4. $CO_2$ management storage trials summary

| | |
|---|---|
| Varieties | Taurus, Arsenal |
| $CO_2$ levels to be tested | 0.3 % and 1% constant level, 0.3% with a monthly period at 1% to mimic treatment application, 1% with monthly short periods of 10 ppm ethylene |
| Storage conditions & sampling regime | 9°C stores; sampling at 3-, 6- and 9-month intervals |
| Assessments | Weight loss, sprouting, fry colour (crisping) |


CIPC being applied to potato stores

## Legacy of CIPC: Residues in store fabrics

CIPC residues are long-lasting and can be found in store fabrics and flooring many years after the final application. With the loss of approval, residue persistence will have significant implications for the future.

The Maximum Residue Level (MRL) for CIPC is currently 10 mg/kg. Following the withdrawal of approval, the MRL would normally revert to the Limit of Quantification (LOQ, 0.01 mg/kg). In recognition of the difficulties with residue persistence, AHDB has submitted an application for a temporary MRL (tMRL).

This project (11140059) is assessing levels of CIPC contamination from UK stores, with a range of historical applications of CIPC to support this application.

In 2018, it was found that in the 11 stores assessed, CIPC was detected at concentration levels of 0.05 mg/kg on average (residue tests performed on tubers, not store fabrics). In the second year of trials, the average levels of CIPC detected were 0.04 mg/kg. Notably, a number of stores, including some in which CIPC was used until very recently, did not exceed the 0.01 mg/kg LOQ threshold. Data from this project was used, as part of a wider European data set, to inform regulators responsible for reviewing the tMRL application. tMRL approval, if granted, would probably be in the range of 0.3–0.4 mg/kg CIPC.


Store concrete floor with CIPC residue

# AHDB-funded research

| Project number | Project title | Lead contractor | End date | AHDB funding | Cereals & Oilseeds | Potatoes |
|---|---|---|---|---|---|---|
| Pests | | | | | | |
| TBC | Improving integrated pest management of aphid BYDV vectors | Harper Adams University | September 2023 | £74,100 | ✓ | |
| 21120186 | Reducing the impact of cabbage stem flea beetle on oilseed rape in the UK | RSK ADAS, Harper Adams University | July 2023 | £240,000 | ✓ | |
| 21120077a | Management of aphid and BYDV risk in winter cereals | RSK ADAS, Rothamsted Research | December 2022 | £190,000 | ✓ | |
| 21120154 (91120154) | Testing insecticide resistance management strategies | RSK ADAS | July 2023 | £138,876 (jointly funded with AHDB Horticulture) | ✓ | ✓ |
| 21510042 | Novel approaches to CSFB control (PhD) | Harper Adams University, Certis UK, AFCP | July 2023 | £36,150 | ✓ | |
| 11120177 | Mineral oils for control of aphid-borne virus transmission | Scottish Rural College | March 2022 | £45,927 | | ✓ |
| 21510022 | Autumn survey of wheat bulb fly incidence | RSK ADAS | October 2021 | £32,000 | ✓ | |
| 21120064 | Genetic basis of winter oilseed rape resistance to the cabbage stem flea beetle (PhD) | John Innes Centre | September 2021 | £70,500 | ✓ | |
| 21120078 | Development of an environmentally sustainable and commercially viable approach to the control of the grey field slug | Harper Adams | April 2021 | £120,000 | ✓ | ✓ |
| 11120009 | Assessing the impact of root lesion nematode (*Pratylenchus spp*) infestations on the production of potatoes (PhD) | Harper Adams University | April 2021 | £69,327 | | ✓ |
| 21510015 | Monitoring and managing insecticide resistance in UK pests | Rothamsted Research | March 2021 | £40,000 | ✓ | ✓ |
| 21120080 | Cereals aphids resistance | Rothamsted Research, RSK ADAS | February 2021 | £7,500 | ✓ | |
| Weeds | | | | | | |
| 11120178 | Potato desiccation | NIAB CUF | March 2021 | £40,000 | | ✓ |
| 21120059 | Investigating the distribution and presence, and potential for herbicide resistance of UK brome species in arable farming | RSK ADAS Ltd | February 2021 | £218,000 | ✓ | |
| 21120023 | Managing the resistance risk to retain long-term effectiveness of glyphosate for grass-weed control in UK crop rotations | RSK ADAS Ltd | September 2020 | £250,000 | ✓ | |
| 2140012101 | Variable rate application of plant protection products – investigations to establish the feasibility and potential cost benefits (PhD) | Cranfield University | July 2020 (Completed) | £54,000 | ✓ | |
| 11120038 | Potato desiccation trial | NIAB CUF | March 2020 (Completed) | £77,373 | | ✓ |

| Project number | Project title | Lead contractor | End date | AHDB funding | Cereals & Oilseeds | Potatoes |
|---|---|---|---|---|---|---|
| **Diseases** | | | | | | |
| 21120062 | Developing guidance for fungicide resistance management: a case study for SDHIs and generalisations for future mode of actions (PhD) | Rothamsted Research | September 2023 | £63,959 | ✓ | |
| 21120068 | Yellowhammer: A multi-locus strategy for durable rust resistance in wheat, in the face of a rapidly changing pathogen landscape | NIAB | October 2022 | £98,002 | ✓ | |
| 11120032 | Blight Fungicide Resistant Management initiative | ADAS RSK | July 2022 | £40,000 | | ✓ |
| 11120034 | Population monitoring and fungicide sensitivity testing of late blight in Great Britain | James Hutton Institute | March 2022 | £254,866 | | ✓ |
| 21120013 | Fungicide performance in wheat, barley & OSR | RSK ADAS, SAC Commercial, NIAB, Harper Adams | March 2022 | £732,234 | ✓ | |
| 21120018a | Monitoring and understanding fungicide resistance development in cereal pathogens to inform disease management strategies | NIAB | March 2022 | £90,000 | ✓ | |
| 21120034 | UK Cereal Pathogen Virulence Survey (UKCPVS) | NIAB, John Innes Centre | March 2022 | £599,965 | ✓ | |
| 21130048 | Barley resistance to Rhynchosporium: new sources and closely linked markers (PhD) | JHI | May 2021 | £70,500 | ✓ | |
| 21120007 | Combining agronomy, variety and chemistry to maintain control of septoria tritici in wheat | RSK ADAS, SAC commercial, NIAB | March 2021 | £155,404 | ✓ | |
| 21120058a | Managing resistance evolving concurrently against two or more modes of action, to extend the effective life of new fungicides | RSK ADAS, NIAB, SAC Commerical, Rothamsted Research | March 2021 | £196,500 | ✓ | |
| 21120035 | Understanding interactions between Ramularia collo-cygni and barley leaf physiology to target improvements in host resistance and disease control strategies (PhD) | SAC Commercial LTD | September 2020 | £54,000 | ✓ | |
| 21120015 | Maximising the effective life of fungicides to control oilseed rape diseases, through improved resistance management | RSK ADAS, Rothamsted Research | March 2020 (Completed) | £160,966 | ✓ | |
| 11120048 | Application of machine learning to blackleg prediction (PhD) | James Hutton Institute | March 2020 (Completed) | £71,400 | | ✓ |

| Project number | Project title | Lead contractor | End date | AHDB funding | Cereals & Oilseeds | Potatoes |
|---|---|---|---|---|---|---|
| **Soil** | | | | | | |
| 21140029 | Predicting crop disease from molecular assessment of the distribution and quantification of soil-borne pathogens (PhD) | Fera, University of Newcastle | December 2021 | £25,000 | ✓ | |
| 91140002 | Soil Biology and Soil Health | National Institute of Agricultural Botany (NIAB) | December 2021 | £858,869 (BBRO co-funding £140,934) | ✓ | ✓ |
| 91140001 | Soils and Water Research Partnership: Rotations | NIAB CUF (Cambridge University Farm) | March 2021 | £1,203,152 | ✓ | ✓ |
| 21140024 | Fostering populations of arbuscular mycorrhizal fungi through cover crop choices and soil management (PhD) | University of Cambridge | September 2021 | £45,250 | ✓ | |
| 21140009 | Maximising the benefits from cover crops through species selection and crop management (Maxi-Cover crop) | ADAS | January 2020 (Completed) | £230,000 | ✓ | |
| **Nutrient management** | | | | | | |
| 21140039 | Winter and spring oats Nitrogen and Sulphur management | RSK ADAS, IBERS | May 2022 | £120,000 | ✓ | |
| 21140040 | Nitrogen and sulphur management for grain protein in winter milling wheat | NIAB, SAC Commercial, Masstock (AGRII) | March 2022 | £179,548 | ✓ | |
| 21140038 | Updating N & S fertiliser recommendations for spring barley | RSK ADAS, SAC Commercial | April 2021 | £139,980 | ✓ | |
| 11140048 | Sulphur recommendations and acrylamide potential (PhD) | NIAB CUF | March 2021 | £83,093 | | ✓ |
| 11140044 | Estimation of determinacy: Improving nitrogen recommendations for potatoes through estimation of determinacy of varieties | NIAB | January 2020 (Completed) | £80,815 | | ✓ |
| 21130004 | Developing enhanced breeding methodologies for oats for human health and nutrition (DEMONS) | IBERS, RSK ADAS | January 2020 (Completed) | £157,841 | ✓ | |
| **Grain quality** | | | | | | |
| 21130058 | Environmental effects on grain protein (PhD) | Rothamsted Research | September 2022 | £72,300 | ✓ | |
| 21130012 | Identification of Fusarium resistance within UK oat breeding lines (PhD) | Harper Adams University | September 2021 | £20,000 | ✓ | |
| 21130040 | Monitoring of contaminants in UK cereals used for processing food and animal feed | FERA | July 2021 | £629,969 | ✓ | |
| 21130024 | Developing systems to control male fertility in wheat for hybrid breeding, enhanced pollen production and increased yield | University of Nottingham | September 2020 | £141,312 | ✓ | |
| 21130005 | Developing new types of wheat with good bread making quality at low protein content | Rothamsted Research | March 2020 (Completed) | £80,000 | ✓ | |
| 21130047 | Specific weight in barley (PhD) | SRUC | March 2020 (Completed) | £69,327 | ✓ | |

| Project number | Project title | Lead contractor | End date | AHDB funding | Cereals & Oilseeds | Potatoes |
|---|---|---|---|---|---|---|
| **Storage** | | | | | | |
| 11140032 | Quantifying effects of potato seed multiplication systems and storage practices on ware production | NIAB CUF & Sutton Bridge Crop Storage Research | March 2022 | £115,000 | | ✓ |
| 11140059 | CIPC contamination of stores | Sutton Bridge Crop Storage Research | September 2021 | £63,580 | | ✓ |
| 11140039 | PhD: Mechanism of cell cycle repression in tubers | University of Sheffield | September 2021 | £8,600 | | ✓ |
| 11910060 | Processing variety trial for ethylene and low temperature storage | Sutton Bridge Crop Storage Research | September 2021 | £75,351 | | ✓ |
| 11911062 | Carbon dioxide and processing quality | Sutton Bridge Crop Storage Research | September 2021 | £40,000 | | ✓ |
| 11140058 | Understanding dormancy in potato | Sutton Bridge Crop Storage Research | September 2021 | £75,000 | | ✓ |
| 11140057 | Integrating alternative suppressants for the fresh market | Sutton Bridge Crop Storage Research | June 2021 | £264,000 | | ✓ |
| 11140056 | Maleic Hydrazide: Optimisation as a sprout suppressant | Sutton Bridge Crop Storage Research | June 2021 | £100,000 | | ✓ |
| 11910061 | Spearmint oil efficacy trial with PPA (crisping varieties) | Sutton Bridge Crop Storage Research | September 2020 | £4,000 | | ✓ |
| 11120031 | Improved seed management to minimise losses due to Pectobacterium Species | James Hutton Institute | August 2020 (Completed) | £204,884 | | ✓ |
| 11120028 | Latent infection of tubers during storage and transit | SASA, Sutton Bridge Crop Storage Research & University of Warwick | June 2020 (Completed) | £63,423 | | ✓ |
| 11140043 | Integrating CIPC Alternative sprout suppressants for the processing sector | Sutton Bridge Crop Storage Research | June 2020 (Completed) | £199,950 | | ✓ |
| **Varieties, genetics and production** | | | | | | |
| 11140054 | Investigation of the potential for precision soil and crop growth mapping to improve tuber size distribution at harvest | Harper Adams University | September 2021 | £71,400 | | ✓ |
| 212000110 | AHDB Recommended Lists for cereals and oilseeds 2016–2021 | AHDB, BSPB, MAGB, nabim | March 2021 | £7,953,359 | ✓ | |
| 11140035 | Soil management and irrigation interactions affecting root-to-shoot signalling and yield of potato | Lancaster University | March 2021 | £70,500 | | ✓ |
| 21130048 | Barley resistance to Rhynchosporium: new sources and closely linked markers (PhD) | James Hutton Institute | March 2021 | £70,500 | ✓ | |

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