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Legume research at NIAB

In this Issue

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New Bill fast-tracks future crop development

On 23 March 2023 the Genetic Technology (Precision Breeding) Bill was given Royal Assent, becoming an Act of the UK's Parliament. This is one of the first times we have seen new legislation seeking to enable, rather than restrict, the use of advanced genetic technologies for agriculture and food production in England.

This Bill takes technologies that are more precise than traditional crop breeding out of the scope of GMO regulation, enabling the use of genome editing to fast track the development of crops that will help us to meet the demands for resource-efficiency and climate-ready varieties.

As recently put by Rory Riggs, a US pioneer crop biotechnologist, the development of precision breeding "*is almost an analog-to-digital moment for a new breeding industry*". At NIAB we have supported the passage of this Bill through Parliament as we believe this is great new tool for the breeders' toolkit. I was therefore pleased to see that the BBC came to NIAB to announce this milestone; we have invested in the development of new genetics tools to support breeders and scientists, and some of our more recent buildings have been specially designed to enable the delivery of these type of tools.

As we face the global challenges associated with climate change and feeding a growing population, the continued access to genetic innovation in plant breeding will be one of the most important tools in helping us move forward.

This issue of *Landmark* is, for instance, focused on the work we do to improve legumes genetic resources. We all agree that grain legumes for both animal feed and human consumption will need to have a more prevalent role in UK crop rotations. Articles in this issue explain in detail how legume crops such as peas, beans and soy offer many benefits, including the ability to fix nitrogen and the opportunity to enhance the human diet with plant protein products.

Throughout history we have seen dramatic improvements in agricultural productivity through advances in crop rotation, improved farming techniques, the development of crop protection products and the availability of fertilisers. Precision breeding techniques open a door to expanding our capabilities in plant protein genetics. More broadly, the adaptation of plants to climate change can also be accelerated with precision breeding technologies such as gene editing.

As an example, it is well known that roots with steeper angles support plants that can access moisture at deeper levels. This is a key trait in crops that can maintain high yields in periods of drought. Gene editing can be used to help us understand the underlying molecular mechanisms controlling root growth and architecture. This could allow us to select crops that can still be successful in hotter conditions such as those seen in summer 2022 across Europe; almost no rain was recorded in June and July, and temperatures above 40°C were reached for the first time in several Northern countries.

We are very excited about the breadth of the application of precision breeding. Its relatively low cost has contributed to the democratisation of the technology which will be a catalyst for innovation and attracting private investment. It is therefore important that innovators, breeders and growers are confident that the use of gene editing in the development of improved crops will not be penalised due to unjustifiable stringent and disproportionate near-market requirements.

It is clear that the risks from gene edited crops are no greater than from conventionally bred ones. In the context of the new legislation, we should recognise the safety record delivered by the current rules governing plant breeding and the approval of new varieties. Approaches that combine biotechnology with traditional breeding, new data-intensive tools and agronomic expertise will be needed to design, implement and deploy novel crops.

As the new Act is implemented, law-makers and regulators will feel the responsibility to ensure the benefit can be fully realised by enabling not only research but a route to market. A proportionate and science-led approach to regulation of genetic technologies in agriculture is a critical piece in the jigsaw to ensure we can continue to feed the world whilst protecting the environment.

Professor Mario Caccamo is NIAB Chief Executive appointed in October 2021. He originally joined NIAB as the Head of Crop Bioinformatics in 2015 before taking the position of Managing Director of NIAB EMR in 2017. A computer scientist by training, Mario has over 20 years' experience in life science research and big data, including specific projects to apply the latest DNA sequencing technologies and bioinformatics methods to advance scientific understanding of crop genetics and the interaction of agricultural crops with their environment.

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Pulse breeding at NIAB

Pulse crops, e.g. peas and beans, are grain legumes that will play increasingly important roles in UK arable rotations. With seeds rich in starch, protein and fibre, they are valuable for both animal feed and human nutrition. Pulses also offer wider environmental benefits: they can fix atmospheric nitrogen into the soil through symbiosis with bacteria that inhabit their root nodules, whilst their nectar-rich flowers help to support bees and other pollinators.

Recently, an almost perfect storm has given urgency to increased UK domestic pulse crop production. Increased fuel and fertiliser prices, exacerbated by the conflict in Ukraine, have made nitrogen-fixing pulses a relatively low-cost cropping option. High levels of cabbage stem flea beetle have made many growers seek alternatives to oilseed rape as a break crop. Consumers are shifting towards more plant-based diets, especially in younger and more urban demographics. Supply-chains are gradually moving away from being so reliant on imports of soybean meal, shipped across the Atlantic from sources with sometimes questionable provenance. Finally, the NFU has set an ambitious target of "net-zero" for greenhouse gas emissions in the agriculture sector by 2040. Increasing domestic pulse production can help address all of these, increasing food security by reducing plant protein imports as well as cutting down on the use of nitrogenous fertilisers in the rotation.

Defra commissioned a recent NIAB-led study, '*A review of opportunities for diversifying UK agriculture through investment in underutilised crops – Defra Project CH0224*', which identified a clear need to diversify our crops. Ideally, growers will cultivate crops that fit well with rotations, are climate resilient, environmentally beneficial and that give good economic returns. Some of the potential legume crops considered here include faba bean, soybean, chickpea and lentil. Many factors currently limit their more widespread cultivation, not least of which is the lack of suitable varieties to give an economically viable yield while fitting into typical crop rotations.

NIAB is a UK leader in pulse crop pathology research, especially into faba bean, pea and *Phaseolus* (common bean) and is also investing in genetics and breeding projects in other pulses such as soybean, chickpea, lentil and lupin. NIAB pre-breeding programmes for these crops are not only targeting higher, economically viable UK yields, but are also looking to improve overall yield stability. For example, legume pests and diseases will become increasingly important as the cropped area increases, compounded by the lack of new (and loss of existing) registered pesticides. There is a need to increase crop tolerance to various abiotic stresses such as the drought and heat witnessed in summer 2022, and to cold and waterlogging (Figure 1). Other agronomic traits targeted include earlier maturity, improved seed set, and making the crop easier to harvest by reducing the risks of lodging and pod shatter. We must also consider nutritional parameters such as increasing protein content and reducing anti-nutritional factors.

Figure 1. Cold tolerance screen in chickpea

Dr Abhimanyu Sarkar is a molecular biologist with over thirty years of experience in legume biology, speed breeding, gene discovery and genomic. He joined NIAB in 2021 where he is helping to develop our position at the vanguard of legume genetics and breeding. This will include building on a strong foundation in faba bean, developing a strong research portfolio in other domestic legume opportunities, and continuing to contribute to the improvement of grasspea and other tropical legumes.

Dr Phil Howell has been a pivotal part of NIAB's pre-breeding group since 2007, working on major pre-breeding projects including the flagship wheat resynthesis programme. He has over 25 years' experience of crop genetics and breeding in oilseed and cereal crops, working within the public and private sectors. Prior to joining NIAB, he spent almost ten years at Syngenta, including five years as senior UK wheat breeder, leading to several successful varieties. His practical experience and credibility amongst commercial peers has helped to cement NIAB's position carrying out pre-competitive breeding research.

UK plant protein sources are dominated by the large volumes of high-quality soybean imported for feed and food manufacturing: a case of 'the right crop in the wrong place'. A major source is the Americas, with concerns about the area of rainforest that is cut down for soybean cultivation, overlaid by consumer hesitancy around intensive farming systems which are reliant on genetically-modified soybean varieties. Closer to home, supplies from Ukraine (where the small number of current 'UK-adapted' varieties are actually bred) have been disrupted since February 2022.

Our soybean programme is evaluating global germplasm for genetics that will allow the crop to better fit the UK rotation. This will be aided by genomics for marker development, trait discovery and for enabling rapid genetic gain through genomic selection techniques. In collaboration with Dr Natasha Yelina of the Crop Science Centre and Elena Bidash, a PhD student funded by The Morley Agricultural Foundation and CTP-SAI, NIAB will enhance recombination to increase breeding cycle efficiency, and explore earlier flowering to bring maturity forwards (Figure 2), leading to soybean varieties that will be able to be grown economically by UK farmers.

Chickpea is a promising crop that is widely used in Mediterranean, Middle Eastern and South Asian cuisines. Although there is a small area grown in East Anglia, the UK market is dominated by imports from Canada, Turkey and India. High protein chickpea flour has many versatile uses including as an egg substitute in processed foods. Our breeding programme has access to germplasm from international collaborators such as ICARDA and ICRISAT, and we are targeting similar adaptation traits to those listed for soybean. As *Landmark* goes to press, NIAB is about to begin an exciting two-year project on UK-adapted chickpea.

Lentil is more drought tolerant crop which, like chickpea, is grown almost exclusively for human food, fetching a premium above more common pulses such as beans. The foundation of NIAB's breeding programme is material sourced from ICARDA and the Germplasm Resource Unit at the John Innes Centre (Figure 3). We are also creating novel alleles for improved traits by mutagenesis, in collaboration with Viridian Seeds. Adaptation, combinability and cold tolerance are the key target traits along with yield parameters. We also have a small programme for long-term lupin improvement. This crop is adapted to temperate climes with the potential to replace soybean in some applications.

The Genetic Technology (Precision Breeding) Act, recently passed by Parliament, promises to jumpstart rapid crop improvement efforts using gene editing techniques. NIAB is well equipped to take advantage of these opportunities: Dr Emma Wallington's Crop Transformation group is active in developing gene editing pipelines for legumes including faba bean, peas, soybean and cowpea.

Of course, improved genetics is only part of the story. Across all these crops, there is an ongoing requirement for agronomy and plant pathology research to ensure that UK growers have a strong evidence-based platform to successfully grow these crops.

Figure 2. US soybean variety only just starting to flower, late August 2022

Figure 3. Replicated lentil variety yield trial at Cambridge in 2022

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Legume research at NIAB

Legumes have received renewed interest recently as important break-crops that can improve sustainability in agricultural rotations by decreasing the risk of pests and diseases, providing greater control of weeds, enhancing soil structure and contributing residual nitrogen to subsequent crops.

The most widely grown legumes in the UK by area are faba bean (700,000 ha), combining pea and vining peas for fresh consumption (each around 50,000 ha). However, lupins, lentils, chickpea and even haricot beans (*Phaseolus vulgaris*) are now being produced commercially as pulse crops, highlighting an increasing demand for these healthy nutritious grains, often as alternatives to meat.

NIAB has a long history of supporting variety registration for plant breeders' rights and disease testing for the pulse descriptive list run on behalf of the PGRO (Processors and Growers Research Organisation), helping to ensure new varieties are characterised impartially and to the highest standards, and enabling growers to select the best performing and potentially profitable variety for their farms.

Faba bean research and development has been established at NIAB for 15 years, with work primarily supported through the DEFRA Pulse Crop Genetic Improvement Network (PCGIN) and other UKRI and EU-funded initiatives. PCGIN continues to provide genetic resources, knowledge and expertise that can be exploited by academia and industry for supporting improvement and adding value to pea and faba bean crops, particularly in terms of quality and disease resistance.

NIAB has been responsible for developing genetics/genomics resources and exploiting natural diversity in faba bean for improving disease resistance against major disease including chocolate spot (*Botrytis fabae*), downy mildew (*Peronospora viciae* f sp. *fabae*), and *Fusarium* foot-rot. We have successfully screened large numbers of diverse lines, identifying novel sources of resistance, mapping the genes involved and then providing plant breeders with linked markers to track the specific regions to crossed material.

Establishing new genetics tools, pre-breeding pipelines and screening strategies for disease and quality through our various collaborative projects has provided a foundation for developing greater legume research capability at NIAB. In recent years' research interests have extended to species like lentil, chickpea and even *Phaseolus* bean. Although historically cultivated in Europe and Mediterranean regions, working on crops from temperate and even tropical regions allows us to interact with overseas collaborators to support crop improvement in developing countries, whilst enabling us to improve our knowledge and considering how to address similar types of challenges to agriculture in the UK. Limiting the effects from a variable climate, such as drought or heat, and avoiding disease caused by an array of different pathogens are key strategies for maintaining yield and quality in many crops. Understanding how to mitigate against these are of course major priorities for the legume programme at NIAB.

Dr Tom Wood is a senior programme leader in the pathology and entomology group at NIAB. His research aims to integrate classical pathology, genetics and genomics approaches to investigate crop pathogen diversity, identify new and novel sources of host-resistance and develop enhanced pathogen detection and diagnostics strategies. The ultimate goal is to help improve crop protection efforts and to enhance productivity and quality. His current research is focused on improving disease resistance in faba bean against a range of pathogens and developing molecular pathotyping approaches in pulse downy mildews for guiding variety testing and deployment.

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Developing hybrid beans

Dr Tom Wood – see page 6

A major legume research initiative over the past five years at NIAB has been the Global Challenges Research Fund – Bioinformatics and Biological Resources Project (BB/R01504X/1) *Developing a hybrid bean collection to advance climate-ready bean breeding* (for more information search for 'hybrid beans' on niab.com).

Originally conceived by former NIAB colleague Dr Sarah Dyer (now Non-Vertebrate Genomics Team Leader at EBI-EMBL), the project has enabled researchers at NIAB to collaborate with CIAT Bioversity International's bean germplasm resources and breeding teams (Dr Marcela Santaella, Javier Gereda, Dr Peter Wenzl, Dr Steve Beebe and expert botanist Dr Daniel Debouck) to characterise a set of seven domesticated/wild interspecific hybrid complexes of common bean (*Phaseolus vulgaris L.*) and its sister taxa *P. coccineus*, *P. costaricensis* and *P. dumosus* conserved within CIAT's Future Seeds genebank.

The hybrid complexes were collected by Dr Debouck and colleagues during field visits over a number of decades from locations as far north as Durango in Mexico and as far south as Tarija in Bolivia, based on the hybrids potentially useful adaptive variation. Partners at CIAT have been responsible for multiplying seed and assessing the agronomic characters (i.e. habit, height, maturity) of the material grown at a field station in the mountains close to Cali, Colombia. Work at NIAB has prioritised screening for resistance to diseases, variation in stomatal density, and root angle and morphology to aid the identification of useful diversity to support future breeding efforts to resist climate-change.

Figure 1. Wild-hybrid bean complexes growing under glass at NIAB Park Farm. Despite originating in South America, the complexes grew readily in the cooler months of the year (October-April)

Whilst increasing global temperatures are a concern, the UK climate was a consideration for growing bean varieties suited to temperate and tropical region. As some of the hybrids can take six months to flower, we chose to grow the hybrids under glass at NIAB Park Farm in Cambridge (Figure 1). However, this did not seem to limit even the taller, climbing types! Plants were grown to flower, enabling leaves to be sampled for morphological and disease resistance testing, whilst allowing for pollen from potentially useful lines to be sampled for crossing.

Stomata are holes in the surface of leaf that help plants to regulate the rate of transpiration (flow of water) and also heat-loss. It is perceived that a higher number of stomata could confer greater tolerance to high ambient temperatures through the ability to transpire more. Visual assessments for variation in stomata were conducted using nail varnish leaf-imprints which enabled cells to be counted accurately under a basic light microscope and the frequency to be calculated, helping to identify individuals with the greatest average number of stomata (Figure 2 and Figure 3). Specific

Figure 2. Comparing the range of stomatal density in leaf imprints taken from hybrid complexes and parental lines grown in direct light and shade conditions

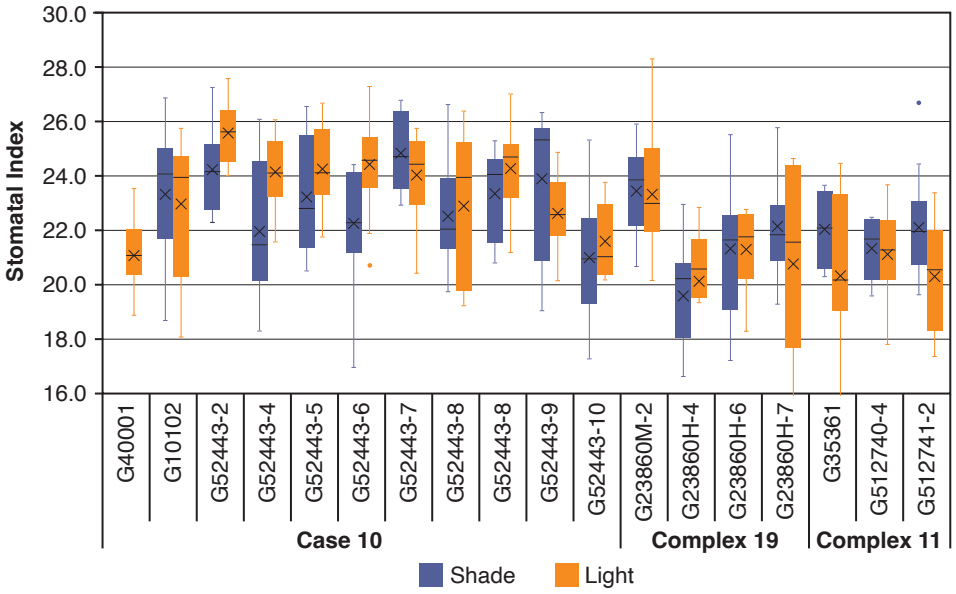


Figure 3. Microscopic image of an imprint from the underside of a common bean leaf showing epidermal cells (irregular shape) and guard cells where stomatal opening occur

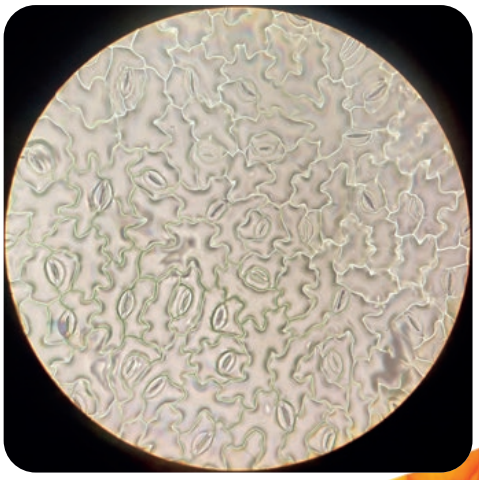
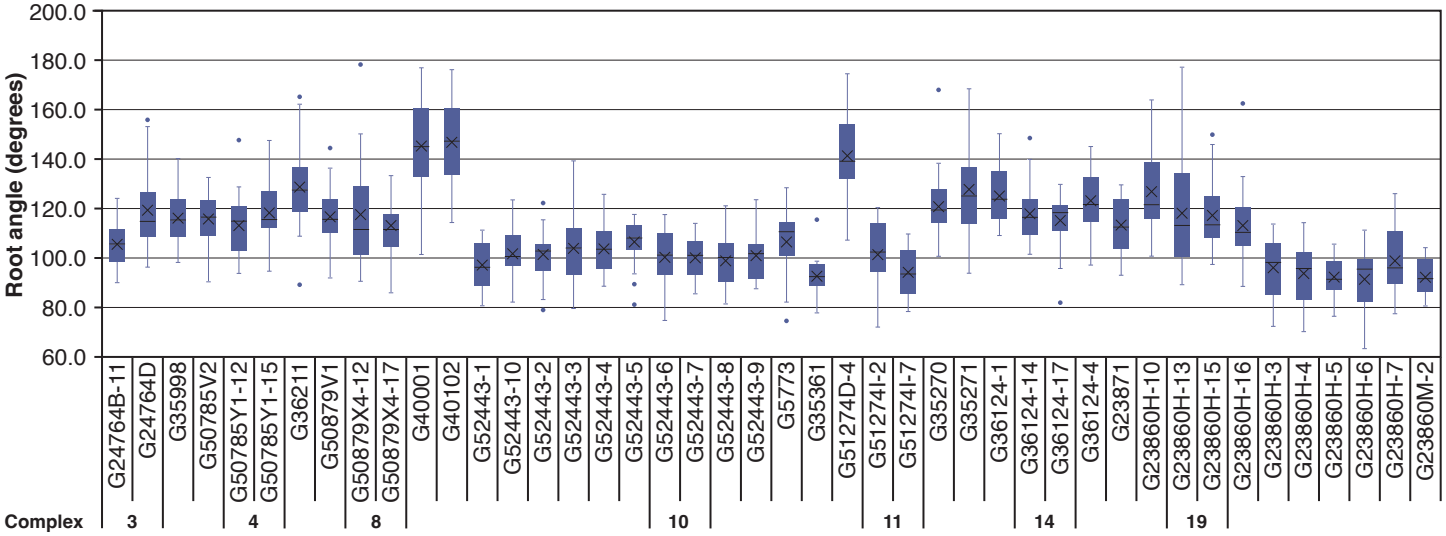


Figure 4. Assessing root angle in 7-day-old seedlings using a clear-pot system. This particular parental line originates from dry regions in Mexico and exhibits a very shallow rooting profile

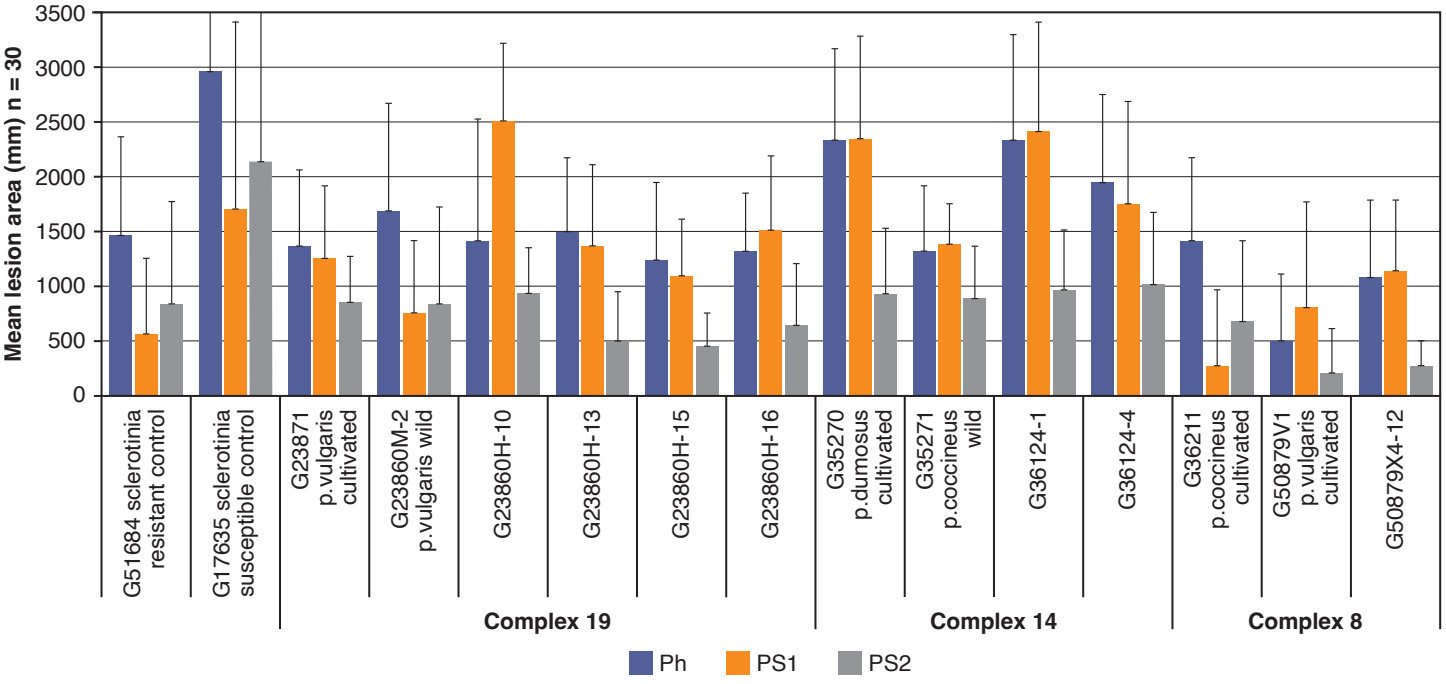


hybrid accessions were identified with approximately 20% more stomata, representing a potentially useful resource for breeding more resilient common bean varieties.

Likewise, variation in root angle provides different benefits to the plant according to the growing environment. For example, hybrids originating from arid regions can exhibit shallower rooting, investing only limited resources in root-biomass, but are potentially more resistant to drought, but enabling the plant capturing any small amounts of rainfall at the soil surface. In contrast, hybrids from

Figure 5. Detached leaf assay demonstrating the symptoms caused by *S. sclerotiorum*

Figure 6. Comparing lesion size caused by three different *S. sclerotiorum* isolates in hybrid complexes, parents and control material, using detached leaf assays



cooler, nutrient-poor environments have can longer, more robust rooting systems that are beneficial in phosphate-poor environments, enabling them to scavenge the additional nutrients they require. Root development in young bean seedlings was compared in the various complexes using a clear pot system first developed in wheat. This enabled lateral root angle to be characterised across the different hybrid complexes (Figure 4), providing information on the potential performance of the respective lines. Promising lines will now be screened more extensively to assess if they are more tolerant to heat and drought.

NIAB staff also conducted an extensive screening programme for resistance to anthracnose (*Colletotrichum lindemuthianum*), root-rot, web blight (*Rhizoctonia solani*) and white mold (*Sclerotinia sclerotiorum*) using a series of detached leaf and seedling assays (Figure 5). The performance of the various individual complexes was compared against resistant and susceptible controls, and helped identify a number of potentially useful sources of (complete and partial) resistance to all four pathogens (Figure 6). The resistant hybrids have subsequently been crossed with a common *P. vulgaris* parent, Ser-16, to evaluate the potential of the different lines for breeding purposes.

Another major component of the project has been genotyping the putative parents and hybrid accessions (using Diversity Array Technologies DArTSeq platform) to confirm the heritage of the respective complexes. Whilst the hybrids presumed parents have been collected from the same collection sites, their provenance is only now being verified using DNA fingerprinting and the respective paternal and maternal lineages determined in the hybrid progeny.

The project has been an excellent opportunity to work with colleagues at CIAT Biodiversity Alliance and EMBL-EBI, to help develop these important genetic resources to support efforts for breeding better performing varieties that are able adapt to more challenging climatic conditions. The trait characterisation data generated during the project will be synthesised into variety portfolios that can be accessed and interpreted easily by researchers and plant breeders looking for novel variation to introduce into their breeding programmes. All the phenotyping and genotyping data will be made available at the end of the project, enabling other researchers to select specific lines that could be useful for their programs, accessing genetic material through the Future Seeds gene bank.

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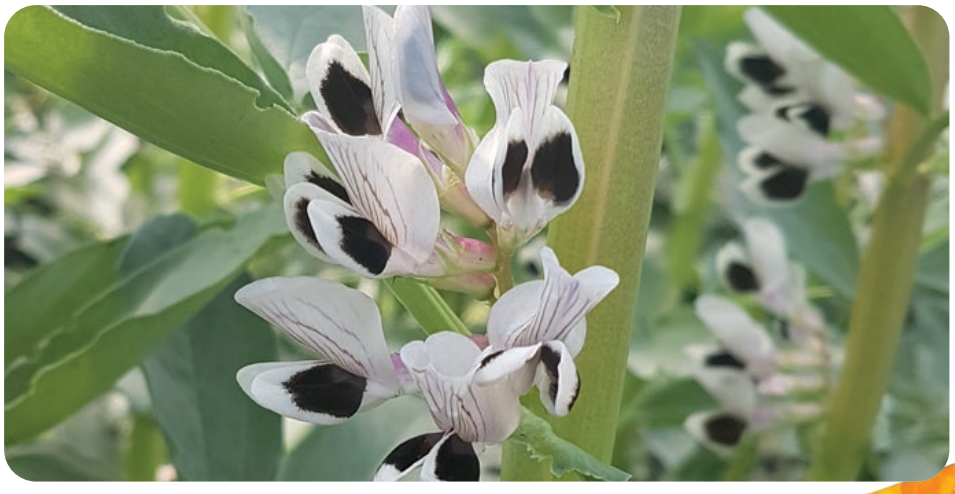
Developing new tools to improve UK food legumes

Dr Tom Wood – see page 6

EAGLE (Enhanced analytical and genetics tools for improving UK food legumes) is a BBSRC Bioinformatics and Biological Resources fund project that began in January 2023 and will run for four years. Valued at just over £1 million the research partners include NIAB, the John Innes Centre and JIC's Germplasm Resource Unit.

The project will facilitate the development of bespoke transformation and regeneration strategies for pea and faba bean using morphogenic regulators to improve efficiency, and test gene editing approaches in both species. EAGLE also aims to characterise sequenced pea and faba bean diversity panels for nutritional quality, e.g. protein, starch, fibre content, and the presence of anti-nutritional compounds, e.g. phytate, trypsin inhibitor in pea and vicine/convicine in faba bean. This takes place whilst conducting multi-site trialling to investigate how genotype x environment interactions influences crop quality, and testing genomic prediction methods as a strategy to improve efficiency in breeding programmes.

Cross-sector stakeholder workshops are planned to promote the new resources and encourage uptake and utilisation. The mission is to provide researchers and industry with a functional resource that can be exploited not only for supporting basic and applied research, but also to provide plant breeders with access to germplasm and technologies to expedite the selection of improved, better-adapted varieties. The project is a great opportunity for NIAB, our partners at JIC/GRU and the legume community to progress applied crop and biotechnology research in the UK.



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Cereal candidate varieties in 2023

With spring on the horizon, the season of open days and variety planning will soon be upon us. As always there will be many varieties to see in the field but what about the candidate varieties for the 2024/25 AHDB Recommended List – what can we expect to see from them? Here we will take a quick look at these varieties and what they might offer, but also come along to the Cereals Event and the NIAB Open Days in June to see them in the field.

Clare Leaman has worked in variety evaluation at NIAB for nearly 30 years. For the majority of this time she has worked with combinable crops and more recently focused on cereals. Much of Clare's work revolves around knowledge transfer within the industry both through the NIAB membership as well as to a much wider audience. Translating data and trial information into a digestible format for the growers and agronomists to use on the front line is a high priority. Clare is widely regarded as a key source of independent variety advice to growers.

Wheat

In all there are 12 new winter wheat candidates that span the end use groups. In the potential bread-making group there is **KWS Dragum** (KWS). KWS Dragum has good yield potential, particularly in the east, along with good resistance to both mildew and yellow rust, although its septoria resistance is not so appealing. It has a good specific weight, and it is currently undergoing baking tests. **LG Partridge** (Limagrain) and **SY Cheer** (Syngenta) also fall into the bread-making group but they are still waiting to complete National Listing, so no information is currently available.

We continue to see a stream of potential biscuit-making varieties, with five candidates of this type in trial this year. While yields in this group have been fairly static, **Bamford** (Elsoms) looks like it may offer the step up needed, with a treated yield up with the better feed varieties and an excellent untreated yield. It has a good specific weight as well as good resistance to both yellow rust and septoria and while it does not have orange wheat blossom midge resistance it does offer Pch1 eyespot resistance, one to definitely keep an eye on.

LG Arkle (Limagrain) also looks promising on the yield front, although not to quite the same level. It is a tall variety with a good specific weight and good resistance to yellow rust although the septoria resistance is not as interesting. **LG Grendel** (Limagrain) has similar yields and is a slightly shorter variety. Although the specific weights are lower it offers good resistance to both yellow rust and septoria. **Almara** (Senova) is a lower yielding variety, although limited data suggests a better performance in the north. It has good yellow rust resistance and moderate resistance to septoria as well as good specific weight. Finally in this group we have **KWS Skateum** (KWS) which is still awaiting National Listing.

Blackstone (Elsoms) is the only soft feed candidate this year. It offers a treated yield similar to LG Skyscraper and an improved untreated yield, with limited data also suggesting a good northern

performance. It is tall but looks to be stiff and has a good specific weight as well as excellent resistance to yellow rust and moderate septoria resistance.

With treated and untreated yields up at the Champion level, **LG Beowulf** (Limagrain) leads the charge of the hard feeds. Top yields combined with a good specific weight, good resistance to yellow rust and moderate septoria resistance, as well as resistance to orange wheat blossom midge make up a package that will be of interest to a wide range of growers. **Bolinder** (Elsoms) is a couple of percent behind in terms of yield but offers a combination of good resistance to both yellow rust and septoria as well as resistance to orange wheat blossom midge. Offering a similar yield package is **LG Redrum** (Limagrain). The variety has shorter straw as well as a good specific weight and offers good yellow rust resistance and moderate resistance to septoria as well as resistance to orange wheat blossom midge.

Depending on what harvest 2023 brings it looks like there could well be some varieties of interest in this group of candidates.

In spring wheat there are two candidates with potential for bread-making but **SEW19-3003SW** (Cope Seeds) is still waiting for National Listing so no data is currently available. **WPB Mylo** (LS Plant Breeding) has shown some good yields combined with short straw and a good range of disease resistance. Quality data will play a big part of the future for both these varieties.

Barley

There are nine winter barley candidates, with one of them, **Demoisel** (Agrii), under test for malting. Demoisel is a six-row variety that looks to have a competitive treated yield, a good specific weight and moderate to good resistance to Rhynchosporium and net blotch, although it is very susceptible to mildew.

The two-row feed candidates are led by **LG Capitol** (Limagrain) which offers very high yields both treated and untreated. It has moderate resistance to Rhynchosporium and has shown some susceptibility to net blotch. **Resolute** (Agrovista) has a slightly lower treated yield but a good untreated yield with slightly improved Rhynchosporium resistance. **Aleksandra** (Agrovista) has a similar treated yield and disease profile but offers an excellent specific weight. Its straw characters however require further investigation due to limited and variable data.

Valvira (Elsoms Ackermann) is a conventional six-row with good treated yield. However, its straw characters require further data to form a clear view. Its specific weight is also on the low side, but it does have the benefit of good Rhynchosporium resistance as well as BYDV tolerance which can be a useful tool out on farm.

SY Loona (Syngenta) is a high yielding six-row hybrid variety. It has tall straw, which limited data currently suggests has reasonable strength. SY Loona offers excellent resistance to Rhynchosporium which will be useful out on farm.

SY Buzzard (Syngenta) is a six-row hybrid which also offers tolerance to BYDV as well as a good treated yield. It is very tall but has shown reasonable straw strength based on limited data as well as good resistance to Rhynchosporium. **Valiant** (Elsoms Ackermann) and **SY Harrier** (Syngenta) are all waiting to complete National List testing.

There are 12 spring barley candidates and all bar one of them are awaiting National Listing, so at this stage we can only comment on **RGT Celest** (RAGT) which is a high yielding variety with short, stiff straw and a moderate disease profile.

Oats

Oat varieties do two candidate years in trial, rather than the more normal one, to amass sufficient data, and this year we have no winter oats that will be up for Recommendation in the autumn. However, there are two spring oat candidates to review as well as a new naked variety.

Zenith (Senova) is a very high yielding conventional spring oat. It has shown some susceptibility to both mildew and crown rust and has a good kernel content, but its specific weight is borderline. **Asterion** (Saaten Union) is slightly lower yielding but still competitive, especially if it proves its worth in the mill. It too has a good kernel content but an improved specific weight. It has excellent resistance to mildew but has shown some susceptibility to crown rust.

Finally, we have **Ovation** (Senova), a naked oat, which offers a good yield and improved disease resistance compared to the other naked oats. Its specific weight is however on the low side and screenings on the high side.

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NIAB Viticulture: the science of quality

The English wine industry is embracing the scientific viticulture expertise at NIAB in East Malling to develop both improved production techniques and wine quality.

The rapid expansion of vine growing in the UK over the past decade reflects the burgeoning English apple and pear industry over a century ago. Indeed, it was the growth of fruit production in Kent and the South East that led to the founding of East Malling Research Station in 1913, an establishment that developed into the world renowned centre of excellence that we know today under the NIAB name.

Much of NIAB's success at East Malling has been built on employing scientists from a wide range of disciplines who have become experts in their field. Together, they have engaged directly with fruit growers to research and develop solutions to their problems and help to increase yields and fruit quality, allowing local growers to remain profitable and compete on the world stage. NIAB's famous series of apple rootstocks at East Malling, its pioneering work on apple storage technology and development of modern high-yielding strawberry varieties, has been achieved by multi-disciplinary teams collaborating closely with the industry.

Fast forward to 2023 and NIAB finds itself engaging with a new viticulture industry, drawing on a team of experts who can help to research the production of grapes in our UK climate, and the quality of wines made from these grapes.

With climate change apparently occurring at swift pace, an increasing number of fruit growers have spotted the opportunity of growing high quality grapes for wine production in southern England. Alongside this new opportunity however, climate change brings major challenges, including more variability in terms of temperatures, light, rain and more extreme weather events such as hail, late frost, heatwaves, rainfall and drought. These variables do not necessarily have a negative impact on wine quality, but always influence plant physiology and therefore the wine produced (vintages, sugar/acid, varieties). As a result, some leading vine producers have sought NIAB's help.

This led to the first planting and establishment of a research and development vineyard at East Malling in 2015. The vineyard has been set up both for research purposes and to demonstrate best practice in vine growing, and it has been designed to reflect NIAB's successful WET (Water Efficient Technologies) Centre which was established to demonstrate science into practice for the soft fruit industry. Above all, it is a unique, randomised, replicated facility, enabling robust R&D investigations.

The aim of the applied research is to improve berry yields and juice quality, whilst using resources responsibly and sustainably in ways that can be implemented in the UK's cool-climate commercial vineyards. To this end, the vineyard has been planted and laid out in a way that ensures our research is directly applicable to commercial practice and provides an essential facility to test upstream innovative practices or novel ideas of research in viticulture.

The demonstration work and research programme is guided by the industry

Scott Raffle is NIAB's Senior Knowledge Exchange Manager, raising the profile of the research and commercial activities at NIAB East Malling and improving collaboration between researchers and the fruit and wider horticulture industry.

Dr Mark Else is Head of Crop Science and Production Systems at NIAB East Malling, focusing on understanding and manipulating crop and environmental interactions to deliver improved resource use efficiency, crop productivity and quality of fresh produce. This includes the development and integration of precision irrigation and fertigation systems into commercial production to help improve on-farm resource use efficiency, plant productivity and consistency of produce quality.

funders, currently comprising four major wine producers – Chapel Down, Gusbourne, MDCV and Nyetimber – along with irrigation specialists Netafim UK Ltd. Three new associate members bring additional support including Yara UK Ltd (Bespoke fertigation programmes to newly-planted and established vines), Hutchinsons (agronomy support) and Hampton Steel Ltd (canopy support and training systems).

Early plantings have demonstrated the performance of a range of varieties on different rootstocks and using different training systems (Lyre, Guyot Double and a Malling system). The scientists have also been able to stage machinery demonstrations including methods of mechanical weed control and this has been employed in a European funded research project (IWMPRAISE) to compare the efficacy of mechanical weed control with conventional herbicide treatments. Both of the mechanical weeding methods assessed were as effective as herbicide treatments in terms of vine vigour and yield and did not result in losses in berry yield or quality. Interestingly, the control vines (no weed control) were chlorotic, nutrient deficient and produced only one third of the yield recorded for the weeded vines.

NIAB's soil scientists are increasingly aware that poor soil health can give rise to inconsistent yields and juice quality in vine growing, which can lead to costly interventions in the vineyard and winery. Working with Chapel Down and Gusbourne and an industry consortium, earlier this year NIAB successfully secured grant funding from Defra's

Farming Innovation Programme (FIP) to investigate the potential impact of groundcover management practices on soil health, yields, juice quality and emissions. It will also lead to grower guidance on bespoke cover crop mixes to alleviate soil compaction, improve soil nutrition and control nematodes. Guidelines to support transition towards net-zero carbon emissions will be drawn up alongside this.

In 2022 NIAB established an additional research vineyard as part of its 'trials services for horticultural crops'. Consisting of Pinot Noir and Chardonnay in 24 rows (60 vines per row), it offers the opportunity to undertake agrochemical trials, which require 'crop destruction' where new and emerging chemistry is being assessed. With no grapes being harvested for sale or for juice, it is thought to be the only vineyard of its kind in the UK. During its establishment, a root treatment trial was also instigated in this vineyard.

With so much science being channelled into grape growing, the funders of the research vineyard at NIAB recognised the importance of linking production to wine quality and with this in mind, a small research winery was created at East Malling in 2018. This allows NIAB to directly assess the impact of the research and different growing practices on the final wine product. The wines produced are regularly tasted and assessed by the funding consortium which is chaired by Geoff Taylor, who has 35 years of experience both working in the wine industry and employed in food and drink research.

Having outgrown the small winery, the consortium and NIAB have benefited from recent capital investment from Growing Kent & Medway, a research, innovation and enterprise cluster which is supported by UKRI's Strength in Places Fund. As part of a complex of new research facilities at East Malling, a new Wine Innovation Centre (WIC) has been built. Covering an area of 260m^2, it includes a fermentation area, temperature-controlled cellar, pressing area and analytical laboratory. With this new infrastructure in place, the final piece in NIAB's viticulture research programme is the appointment of Dr Belinda Kemp, a world-leading oenologist, to work with the UK viticulture industry and steer our research to meet the needs of our wine producers.

Varieties and Rootstocks

Varieties: Pinot Noir, Pinot Meunier, Chardonnay, Bacchus, Divico, Pino Blanc

Climate change varieties: Sauvignon Blanc, Chenin, Merlot, Chasselas, Gamay, Vlognier

Rootstocks: 3309C, S04, 5BB, 101.14, Fercal

Charlotte Nellist • charlotte.nellist@niab.com

UKCPVS: initial results from the 2022 season

Dr Charlotte Nellist is a group leader in pathology with interests in disease resistance characterisation on a wide range of crops and understanding how pathogens interact with hosts. She manages the UK Cereal Pathogen Virulence Survey (UKCPVS).

The UK Cereal Pathogen Virulence Survey (UKCPVS) monitors the populations of the important cereal pathogens *Puccinia striiformis* f.sp. *tritici*, causing wheat yellow rust, *Puccinia triticina* causing wheat brown rust, *Blumeria graminis* f.sp. *tritici* causing wheat powdery mildew and *Blumeria graminis* f.sp. *hordei* causing barley powdery mildew. The Survey is funded by AHDB and Defra and has been managed by NIAB since its inception in 1967 following an unexpected outbreak of yellow rust on the previously resistant variety Rothwell Perdix.

The warm weather experienced across the UK accelerated the 2022 disease epidemic and the Survey finished considerably earlier than previous years, with the last sample sent in on 29th June 2022, compared to 22nd July in 2021. The weather also brought an unfamiliar foe to our shores; with widespread infections of stem rust observed in June and July.

Wheat yellow rust

UKCPVS received a similar number of yellow rust samples as 2021, with 187 samples received across the season. There was a slow start to the Survey, but the 2022 season was an interesting one, with the extended warm period resulting in an accelerated season and a shift in the epidemic. The Survey received the majority of samples (120) in May, dropping to just 40 samples in June, normally when the majority are received. Yellow rust samples were received from 27 counties around the UK with most samples, unsurprisingly, from Lincolnshire, Cambridgeshire and Norfolk. As with previous years, UKCPVS also received samples from traditionally lower risk areas for yellow rust, including Scotland, Wales, Northern Ireland and Devon, covering a wide geographical area.

The Survey received samples from 52 different varieties. The most prominent variety was KWS Zyatt (Recommended List [RL] resistance rating 3), closely followed by Skyfall (RL rating 3). Four samples with very low infection levels were received from KWS Siskin (RL rating 9). However, none of the isolates tested reinfected KWS Siskin at the seedling stage, confirming that this resistance remains stable.

Using seedling tests, the virulence profile was determined for a selection of 25 isolates. Virulence for Yr1, 2, 3, 4, 6, 7, 9, 17, 25 and 32 all remained very high in the population. Virulence for Yr8 is always closely watched as that has been seen at low levels for the past three years but was not detected in any of the isolates characterised in 2022. No virulence was detected for Yr5, 10, 15 or 24.

Key additional winter wheat varieties are also included in testing. Virulence on KWS Extase remains at low levels, being detected in 8% of isolates. Virulence to Evolution has fluctuated over the past five years and was seen in 40% of isolates in 2022, similar to the level seen in 2021. Virulence for Crusoe remains at low levels, detected in 8% of isolates. No virulence was detected in any of the isolates for KWS Firefly or KWS Siskin.

Two new pathotypes (combination of virulence genes) were identified during 2022; the isolates were sampled from Norfolk and Shropshire. The isolate from Norfolk was selected for inclusion in the adult plant trials conducted in 2023, so the risk to UK varieties from this new pathotype and four others will be investigated further.

UKCPVS has deployed routine genotyping of wheat yellow rust isolates, based on Dr Diane Saunders' (John Innes Centre) MARPLE pipeline (Mobile and

Figure 1. Example symptoms of wheat plants infected with stem rust in Oxfordshire in 2022

Real time PLant disEase diagnostics). Genotyping is categorising an individual, based on its collection of genes and enables us to see if a completely different genetic group appears in the UK yellow rust population. The Red Group, previously known as Warrior 4 or Warrior(-), has dominated for the past four years. Twenty-three of the 24 samples genotyped in 2022 belonged to the Red Group. This group remains very diverse, with a broad range of virulence profiles present, as previously mentioned. Over the past four years, genotyping has helped identify unusual isolates from the Pink Group (Warrior) and the Purple (Kranich) Group. NIAB will continue to genotype a selection of isolates in the 2023 season.

Currently the AHDB RL yellow rust disease ratings (1–9 scale) reflect the resistance status of the plants at the adult stage. Some varieties are susceptible at the young plant stage but resistant at the adult plant stage. UKCPVS assess the threat of five isolates of yellow rust to the full set of Recommended and candidate varieties as young plants at the seedling stage (as well as at adult plant stage). From the current 2023/24 edition, this data along with data from RL trials before growth stage 55 (half of ear emerged above flag leaf ligule) are combined to give a yellow rust young plant resistance rating (r – resistant or s – susceptible) and is published as a separate line in the RL tables.

Looking ahead to the 2023 season, at the time of writing, only three samples have been received by the UKCPVS team, similar to the number received the same time last year. The recent cold weather will have slowed down yellow rust development, but growers are advised to monitor all varieties carefully this season and to report unusual levels of disease to UKCPVS as soon as possible.

Wheat brown rust

The consistent warmer weather experienced in 2022 also brought more wheat brown rust samples into the Survey. We received twice as many samples as 2021, with 28 samples from across England. This was also the first year that AHDB released the brown rust Watch List. Updated annually the Watch Lists are designed to flag any varieties that behave differently to their RL rating and provide early warnings of any rating erosion. Overall, the brown rust Watch List does not suggest there is much to be concerned about. Similar to yellow rust, most varieties are presenting in accordance with their RL rating. The UKCPVS adult plant trial data from the five isolates of yellow rust and five isolates of brown rust support and validate the two Watch Lists and did not highlight any significant differences to RL ratings.

Reports were received of an unusual sighting of 30% brown rust infection on Theodore (RL brown rust resistance rating 8) in Devon. Unfortunately, a sample was not sent into the Survey, but one from Dorset was received where foci of 10% infection was reported. This isolate, along with two others, carried virulence to Theodore at the seedling stage (12% of isolates) and has been selected to be included in the wheat brown rust isolate mix for the Variety Listing (VL; formally known as National Listing) and RL inoculated trials in 2023.

Figure 2. Limited symptom development in two winter wheat varieties during seedling screen of stem rust on Recommended List and candidates

Stem rust

Widespread infections of stem rust (also known as black rust; *Puccinia graminis* f. sp. *tritici*) were seen across England and Wales in the summer of 2022 (Figure 1). Symptomatic plants were detected from at least 12 locations. The widespread occurrence of stem rust was due to the combination of environmental conditions; a Saharan dust cloud brought airborne urediniospores from Europe and North Africa to the UK which, along with the consistent warm temperatures experienced in 2022, led to the extensive incursion of wheat stem rust, not seen for decades.

Due the widespread incursion of stem rust, the UKCPVS team screened two single pustule isolates on the full set of Recommended and candidate varieties. The seedling test demonstrated that the majority of varieties were susceptible at the young plant stage. Two winter wheat varieties showed limited symptom development, with Theodore demonstrating resistance and RGT Wolverine limiting pustule development (Figure 2). Their adult plant resistance was not determined in this trial, but it appears that many UK varieties do not possess all-stage resistance to stem rust. Good control levels are reported with rust-active azole fungicides, particularly tebuconazole.

We need your help

UKCPVS relies on samples of interest sent in by growers, agronomists, and breeders amongst others. This year the Survey is focusing on wheat yellow and brown rust and we welcome samples from all RL and RL candidate varieties from across the country. It is important to receive representative samples from around the country to get an accurate picture of what is happening in the rust populations.

Full sampling details are available on niab.com – search 'UKCPVS sampling' in the search box.

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Goodbye BPS, hello ELMS

The challenge to farmers from the Government is to produce food whilst simultaneously protecting the climate and biodiversity, all the while earning a livelihood and generating profit to invest in business development.

Not a new challenge, but financial support from the Government will increasingly hinge on delivering things other than food, such as minimising emissions, protecting habitats, and improving natural capital. The Government has taken the opportunity of Brexit to review the basis on which English farmers receive subsidies; similar reviews are on-going in Wales and Scotland. But because agriculture is a devolved matter, the resulting frameworks will be different.

In each case, the new framework for farming support links new payments for farmers to actions that will cost farmers to deliver but will help the Government to achieve its legally binding environmental and climate targets. This is set out as part of the *25 Year Environment Plan now revised as the Environmental Improvement Plan (EIP 2023) for England*. The EIP 2023 sets out how the Government will work

Devolved aspects

England

Focuses on 'Public money for public goods', private markets are actively encouraged.

Wales

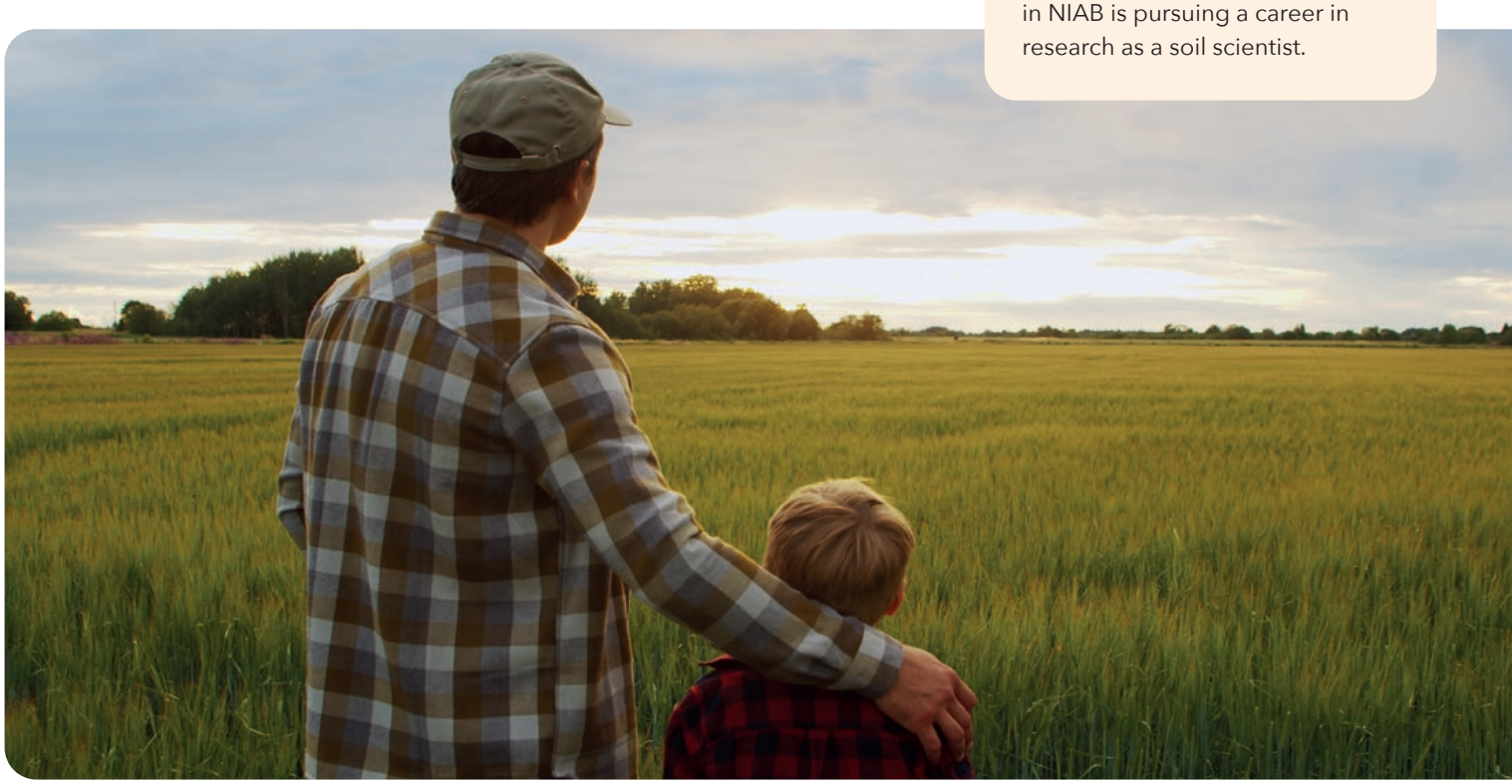
Stronger environmental baseline and social protections, principles of natural capital intrinsic to Sustainable Farming Scheme, much more farmer focussed – on-farm delivery not private investment.

Scotland

Also strong environmental baseline and social protections. Explicitly based on net zero targets, private markets underpinned by Principles for Responsible Natural Capital Investment and contextualised by land reform.

Greg Crawford has a strong passion for business, farming and the environment, which led him to study agricultural business management at Newcastle University. He went on to work for various agri-businesses working across arable, beef and horticulture before joining NIAB in 2022 as the farm business resilience consultant. Greg's role is visiting participants of FFRF to complete the farm business review and report that forms the initial stage of the FFRF support, before signposting to specialist technical advice across the three organisations.

Alex Muxworthy has a BSc (Hons) in Geography and a master's degree in Environment and Development from Lancaster University. She is currently at NIAB on a six month placement as part of the the MDS Graduate Scheme training programme. Alex's research background is in soil science, and after her placement in NIAB is pursuing a career in research as a soil scientist.



with landowners, communities and businesses to deliver goals for improving the environment, matched with interim targets to measure progress. These actions aim to co-ordinate action to restore nature, reduce environmental pollution, and increase England's prosperity.

For most farmers, this is not the first experience of subsidy changes. Eight years ago, the Basic Payment Scheme (BPS) replaced the Single Payment Scheme (SPS). Ten years prior to that the SPS was introduced to counteract over-production of various agricultural commodities, replacing subsidies linked directly to production. These schemes were all part of the EU Common Agricultural Policy (CAP), introduced in 1962 to provide affordable, safe and high-quality food for all European Union citizens. When the SPS was introduced, it removed the link between subsidies and specific agricultural production. This allowed market forces to steer production whilst giving farmers a more stable income which was linked (albeit loosely) to the stewardship of land in good agricultural and environmental condition. Together with BPS, there were additional greening payments, which made up 30% of the total farm support budget, linked with positive environmental delivery by farmers.

Basic Payment Scheme (BPS) reductions

In England, the direct BPS payments are being gradually phased out from 2021 to 2027. On average, over the period 2014-2017, direct payments made up 9% of revenue across all farm types. The proportion of revenue from direct payments was highest on average in grazed livestock systems. Direct payments to arable farms (cereals) made up 15% of revenue on average, equivalent to 79% of the average farm business income. Irrespective of farm size and type, the impact of reducing direct payments on farm businesses is huge. By 2024, depending on area, BPS payments will have reduced by 50-60%. A 250 ha farm which had received £57,500 in 2020 will receive just £26,625 in 2024 and nothing in 2028 (Figure 1). With wheat prices unlikely to reach the highs of 2022 and fertiliser prices up 100% from 2020, farms have been left wondering if the schemes will be able to fill the gap left by the loss of BPS.

New funding replacement

As the BPS is phased out, Defra has confirmed that the same overall spend of £2.4 billion is available to farm businesses until the end of this parliament 2024/25, through a programme of interlinked schemes including: the reducing BPS payments, the emerging Environmental Land Management scheme (ELMs), together with grants to support farm investment in new technology and business support and technical advice funded via the Future Farming Resilience Fund (FFRF). To ensure financial resilience, farmers need to explore all the options available to see how they can be stacked to bring the most value and strength to the farm business.

It should be noted the very public goods that farms are now being incentivised to deliver through ELMs are not mutually exclusive from direct benefits to the farm. Being paid to improve soils can reduce input costs, reducing the use of insecticides can increase the beneficial insects on farm. Taking actions to baseline and then increase organic matter in the soil may also pay off once the carbon credit market becomes more regulated and secure.

Environmental Land Management scheme (ELMS)

ELMs provides payments to reward environmental land management: "public funds for public goods". Defra's aim is to support the rural economy as well as contribute to the commitment to meet net zero emissions by 2050.

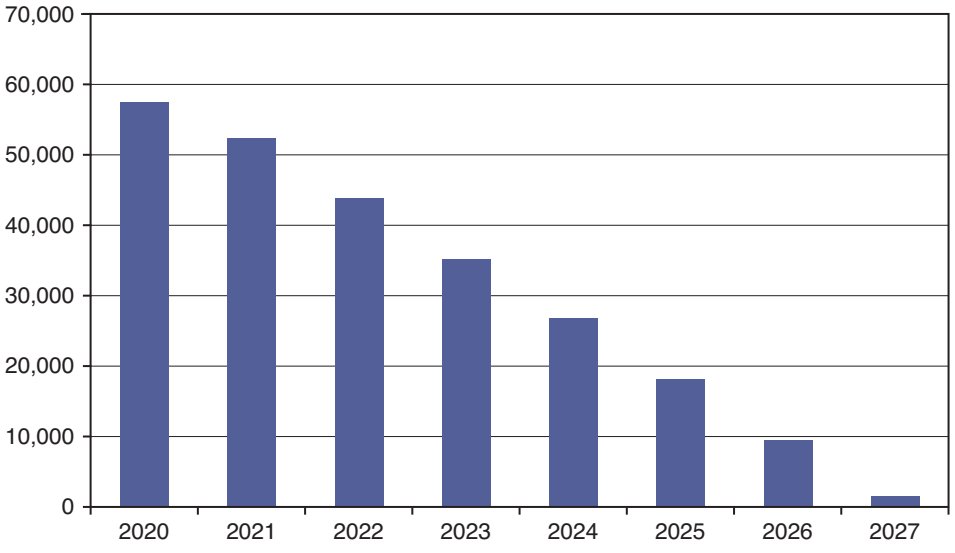
ELMs is made up of a number of schemes that gradually increase in their level of ambition and scale, starting with the **Sustainable Farming Incentive** (SFI) targeted at all farms which focuses on sustainable environmental food production.

Some, but not all farms, will also benefit through **Countryside Stewardship Plus** (CS plus) which targets actions to 'make space for nature' within farmed landscapes. This will now be delivered by enhancing the existing Countryside Stewardship scheme by:

- existing CS standards are likely to be retained but are under review and will be more outcome focused;
- payments are increasing by 10% on average with some capital grants with increases of 48% compared with 2022 levels;
- an additional 30 actions will be added by 2024 to deliver the intentions of the Local Nature Recovery scheme proposed originally.

The final tier is **Landscape Recovery** which will fund long-term, large-scale ecosystem recovery across catchments and landscapes. The first round of applications was funded in autumn 2022. The majority of projects involve groups of land managers and farmers, including tenants, working together to deliver a range of environmental benefits across farmland and rural landscapes. Together,

Figure 1. BPS annual payments (£) on a 250 ha farm



they aim to restore nearly 700 km of rivers and protect and enhance 263 species across over 40,000 ha.

Defra's intention over the next couple of years is to merge all the SFI and CS plus applications into one easy to use online format to minimise the amount of administration and paperwork required by farm managers.

The Sustainable Farming Incentive

The SFI focuses on helping farmers manage their land to simultaneously improve food production as well as be environmentally sustainable. SFI is the first of the three tiers; it is designed to be as accessible as possible, with Defra allocating the main portion of the farming budget in the hope that the majority of farmers will sign up. SFI is intended to encourage farmers to go beyond regulatory baselines. Individually, the payment rates for each SFI standard may look unappealing, however, when you start stacking the various standards, as intended, the overall payments begin to look more attractive.

Exploring the options for the earlier 250 ha arable farm, by taking a pick and mix approach to the SFI standards, the business can start to bridge the funding gap resulting from the diminishing BPS payments. For example, by implementing a few additional targeted actions to plan and monitor soils, nutrients and crop health as well as focusing on hedgerow management, the farm business can receive payment for a number of new SFI actions (Figure 2).

Defra has taken a fair and flexible approach to encourage farmers to participate. The way in which it has been structured means that the SFIs are a very low risk option to enter:

- three-year agreements with no penalty for exiting;
- paid quarterly to help with cash flow;
- some of the actions are rotational so that farmers can incorporate them where they fit best into their farm system and crop rotation;
- farmers can enter SFI if they expect to have management control for 3 years. This means more tenants can access SFI compared with previous schemes. This includes farmers with tenancies on a 'rolling' year by year basis;
- eventually SFI applications will be able to be submitted at any point in the year and new SFIs can be added on as they become available;
- SFIs can be paid on land already entered into Countryside Stewardship (and CS plus) if the actions of both schemes are met and payments are not made for the same outcome;
- farmers and land managers have the option to exit current CS agreements without repayment in order to apply for a new SFI agreement.

Figure 2. Sustainable Farming Incentive actions

SFI standard	Payment rate	Amount entered into SFI agreement	Income from SFI
Not using insecticide	£45/ha	167 ha	£7,515
Intermediate arable soil standard	£40/ha	250 ha	£10,000
SFI administration payment	£20/ha	50 ha	£1,000
Nutrient management plan	£589	1	£589
Integrated pest management plan	£989	1	£989
Hedgerow assessment	£3/100m	66 x 100m	£198
Maintaining a variety of widths and heights	£10/100m	66 x 100m	£660
Maintaining 1 tree per 100m of hedgerow	£10/100m	43 x 100m	£430
6m winter bird food strip	£732	5.0 ha	£3,660
		Total income	**£25,041**

Examples of the range of SFI standards

The Soil Standards paying between £20-£58/ha aim to improve soil quality naturally, mitigating the risk of extreme weather on crops and increasing fertility naturally, with payments for soil testing, cover crops, minimising bare soil and the addition of organic matter. For a 250 ha arable farm entered into the intermediate agreement an income of £10,000 could be achieved. With many farms already completing the actions required for the introductory standard, and with an additional administration payment of £20/ha for the first 50 hectares entered, it is certainly an option worth considering.

The Hedgerow Standards paying between £3-£10 per 100m, designed to increase provision of food and nesting resources, increasing biodiversity by managing hedgerows to ensure a variety of widths, heights and increasing the number of trees in hedgerows. Studies suggest that UK farmland bird populations are now less than half of levels seen in the 1970s.

The Integrated Pest Management Standards encourage a sustainable approach to pest management to minimise environmental risks and have a £45/ha payment for non-use of insecticide, potentially bringing in £12,239 for a 250 ha farm, if the payment of £989 made for completing an integrated pest management plan is included. With the addition of a £55/ha payment for establishing a companion crop, this standard has certainly attracted attention.

Enhanced Animal Welfare is to be provided through a yearly funded vet visit to carry out diagnostic tests and provide bespoke advice to improve animals' welfare for an individual farm's context.

One-off grants

In 2023, more than £168 million of funding will be available through a variety of grants. This year's Farming Equipment and Technology grant for various pieces of equipment designed to save time, improve efficiencies and productivity ended on 4th April 2023 but more grants will be coming available throughout this year, including: cattle housing, infrastructure projects, technology and innovation trials. It is worth subscribing to updates relating to the latest grants and funding (search online for Defra 'Funding for farmers and land managers').

Funded support and advice – Future Farming Resilience Fund (FFRF)

Defra has set aside money in the form of the FFRF to ensure that farmers can get access to the support needed to make the most of the new grants and on-going payments replacing the BPS. The support is also intended to allow farmers to assess, adapt and improve their farming systems and business models. Any farmer or land manager with an SBI number receiving BPS payments is eligible for the support. Register for support even if you took part in the interim phase last year, or if you have applied for the exit scheme.

NIAB has teamed up with farm business consultants AKC Agriculture and Savills, to provide broad technical and management support to farm businesses within FFRF support. It covers all areas of farm business management across all sectors of agriculture and land management. So far, we have had many farm businesses sign up to receive free advice, and are on track to supporting 1,000 farm businesses by the end of 2023.

For general information about FFRF and to register for support from NIAB please visitfuturefarmingresilience.com.

Pea and bean testing

Available individual tests

Beans

- Germination
- 1000 seed weight
- *Ascochyta fabae*
- Stem nematodes

Peas

- *Ascochyta pisi* and *Mycosphaerella pinoides*
- Marsh spot
- Seed borne pea mosaic virus

Standard Package	Beans	Germination, 1000 seed weight, seed rate table, *Ascochyta fabae* and Stem Nematode	£108.00
	Peas	Germination, 1000 seed weight, seed rate table, *Ascochyta pisi* and *Mycosphaerella pinoides*	£97.00
Basic Package	Beans and peas	Germination, 1000 seed weight, seed rate table	£59.00

Due to the hot dry summer last year reduced germination percentages, due to shattering of the beans at harvest damaging the embryo, have been recorded. 35% of samples tested were below the standard of 85% germination.

Ascochyta levels remain low, with 6% of field peas samples tested with 0.5% or more *Ascochyta pisi*. Stem nematodes in field beans were present in only 4% of samples tested.

NIAB LabTest

For details on how to send samples for testing and prices www.niab.com/labtest

Send samples to: NIAB Labtest, 1 NIAB Park Farm, Impington, Cambridge, CB24 9NZ

Free postage-paid envelopes and sample bags are available, call 01223 342243 or email labtest@niab.com

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WET Centre technology delivers a new level of precision to soft fruit growers

Scott Raffle – see page 12

Dr Mark Else – see page 12

NIAB's Water Efficient Technologies (WET) Centre at East Malling was set up in 2017 to demonstrate how to use water and fertiliser more effectively in commercial strawberry growing systems. Funded by Berry Gardens Growers Ltd, Cocogreen, Delta-T Devices, Netafim, Stoller and Yara, with additional input from HL Hutchinson and Weatherquest, the Centre also showcases the latest technology that these funders can offer for advanced soft fruit production systems.

With commercial growers typically irrigating their substrate-grown strawberry crops to 15-25% run-off, some early work at the Centre demonstrated how growers could reduce their total water use each season by up to 33%, whilst maintaining the same yields and producing equal or higher quality berries (Figure 1). Combined with precision irrigation approaches, rainwater harvesting and re-use resulted in 90% water self-sufficiency in 2018, despite the very dry June and July in that year. The Centre has since compared reducing the level of run-off to 5% and 10%, without seeing any significant difference in yields between these levels, or any compromise in fruit quality.

A crucial feature of The WET Centre has been the division of the cropping into a 'commercial area', which mirrors typical commercial practice, and an 'advanced area' (Figure 2), which incorporates the latest technologies to more precisely control the phytoclimate. Not only can visitors to the site view this in action, but the scientists are able to make direct comparisons of fruit yield and quality between the two areas and report their results to the industry, allowing businesses to make informed decisions over whether to implement such technology on their own sites.

Comparisons between the commercial and advanced areas in recent years have demonstrated significant differences in fruit yield using the everbearer Malling™ Champion. In 2020, Class 1 yield was found to be 5% higher in the commercial area, perhaps a result of the higher levels of shading in the advanced area, lowering the photosynthetically active radiation (PAR) at the canopy by 3-7%. It is thought that the increased steelwork associated with the roof vents in the advanced tunnels reduces light levels sufficiently to cause this yield difference, and this effect is probably exacerbated by the relatively large rainwater collection gutters. However, the more flexible venting control resulted in a 1°C reduction in temperature in June and July and up to 7°C in August 2020, and so the improved internal climate control from auto-venting could have significant benefits in hotter years.

Figure 1. Measuring run-off has allowed us to demonstrate that levels can be reduced from 25% to 5%

Yield differences have also been recorded between seasons, with Class 1 yields of Malling™ Champion in 2021 being 22% lower than those recorded in 2020. The amount of accumulated PAR at The WET Centre has been measured each season and the lower yields in 2021 could be attributed to lower light levels. The differing yields between the commercial and advanced areas, coupled with differing light levels, prompted the science team to start investigating whether differences in PAR were responsible for the variability in yields between individual rows in the advanced area. Our research so far has shown a strong correlation between light availability (PAR) and Class 1 yields (Figure 3), with the latter differing by as much as 12% in rows just two metres apart within one tunnel bay. This equates to a yield differential of over 11 t/ha.

There are six rows within each tunnel bay and further investigation revealed that the middle rows (2, 3, 4 and 5) were producing higher yields than the outer rows (1 and 6), with the highest yield being produced in Row 4. Using an array of precision environmental sensors manufactured by Delta-T Devices, a correlation was found between the highest yields per row and the amount

of light reaching the canopy, so a comparison was made between Row 4 with Rows 1 and 6. Row 4 was found to receive two hours more PAR per day than Row 1, but strangely, despite both being outside 'leg' rows, Row 1 produced higher yields than Row 6. Why?

Like other plants, strawberry has a light saturation point, when photosynthesis plateaus, even with further increases in light levels. We discovered that the efficiency of photosynthesis is highest in Row 4 and also higher in the morning than in the afternoon. We are now testing if the higher-than-expected Class 1 yields in Row 1 could result from the peak in early morning PAR coinciding with the peak in photosynthetic efficiency. The results will inform our next steps to optimise the available light to each row at key times during the day using different techniques and technologies.

Work in 2020 also investigated the effects of a UV-blocking film, originally developed as a non-chemical way of reducing pest numbers, on leaf physiology, Class 1 yields, and berry quality. When compared to Malling™ Champion plants cropping under a clear film, Class 1 yields were reduced by 15% under the UV-blocking film; this was due to a reduction in fruit number as individual berry fresh weight was increased slightly, presumably due to the slightly cooler (1°C) air temperatures under the UV-blocking film. Again, the loss of yield was strongly correlated with a reduction in the cumulated PAR reaching the canopy. Leaf physiology was also changed, with stomatal conductance and photosynthesis being lowered, and while the former response reduced plant transpirational water loss, the latter resulted in a 0.5% fall in the average berry soluble solids content (° BRIX) over the season.

The knowledge gained by The WET Centre team on zonal phytoclimates within the tunnel also has enabled NIAB scientists at East Malling to work with one of our funders, Berry Gardens Growers Ltd, and colleagues at the University of Reading in an IUK project called 'BerryPredictor' to improve harvest forecasts, yield predictions and crop productivity, through the development of thermal time and PAR models.

Figure 2. The Advanced area demonstrates the latest technology

Figure 3. Measuring photsynthetic activity

Most recently, the Centre has expanded to include raspberry tunnels where NIAB is currently growing Malling™ Bella for a Netafim-led InnovateUK-funded project ('SmartFert') on reducing fertiliser inputs and greenhouse gas emissions, using a combination of nitrogen-demand modelling, real-time NPK sensing and precision fertigation. We have also started to test new irrigation technology from Netafim to see if water and fertilisers can be distributed more evenly through the rootzone in a crop where Class 1 yield losses from inadequate fertigation scheduling are common.

The addition of Yara and Stoller to our funding consortium has enabled us to investigate the effects of some novel nutritional and biostimulant products in our commercial area. In 2022, we tested YaraVita's 'Actisil™' and 'BioNue' products to assess the effect on yield, fruit quality and shelf-life in Malling™ Champion, along with an iron product's effect on fruit quality. We also quantified the effects of Stoller's products 'Flower Power' and 'Green Forge' in improving tolerance to, and recovery from, heat stress (a good year to do this!) along with their potential to improve yields, fruit quality and shelf-life. Another Stoller product (N Less Advanced Solution) was used to understand if it allows us to lower nitrogen application rates without incurring and yield penalty.

Anyone wishing to learn more about The WET Centre or potential involvement in the work carried out there should contact wetcentre@niab.com.

Fiona Leigh • fiona.leigh@niab.com

Training the next generation of applied bioscientists

The Collaborative Training Partnership for Sustainable Agricultural Innovation (CTP-SAI) is a £3.6 million six-year PhD programme that began in October 2022, tasked with training the next generation of crop scientists. It aims to tackle some of the biggest challenges in broad-acre agriculture through a collaborative training partnership, working with some of the industry's leading agribusinesses, charities, research organisations and universities. It is funded both by UKRI-BBSRC and the industry partners within the consortium (Figure 1).

As the programme developed a very clear message from the industry consortium was the need for skilled post-doctoral scientists that had a wider understanding of how businesses operate. In response, the consortium has partnered with Management Development Services (MDS), which runs one of the leading graduate placement programmes in the agri-food sector. MDS is providing training in key business readiness skills and will be coordinating high quality placements with our industry partners (Figure 2).

The CTP-SAI is unique in that all the PhD projects are built collaboratively; each studentship is developed with an industry, academic and institute partner to ensure that key questions can be answered in a range of crops that are relevant to each part of the field to fork supply chain.

The collaborative design process has created a very diverse suite of projects. We welcomed our first intake of eight PhD students in October 2022 (Figure 3), and their projects covered crops including lettuce, beans, wheat and potato, with research topics ranging from '*The use of virus induced gene editing in potato to dissect plant microbe interactions*', to '*The application of satellite remote sensing and machine learning for modelling impacts of regenerative farming practices*'. The second cohort of students are currently being recruited, and once again, there is a varied portfolio of crops and research questions in these PhDs.

Legume research is represented in both PhD cohorts; Professor Jim Monaghan at Harper Adams University is supervising '*Realising the environmental benefits of faba beans (Vicia faba L.) via optimised nutrition and nitrogen fixation*', whilst we are currently finalising the recruitment of a student to start researching '*Optimising pollination of Vicia faba for enhanced crop yield and to support biodiversity*', led by Professor Beverley Glover at the University of Cambridge. Both of these PhDs are supported by the pulses research organisation and levy board PGRO.

Project design for the third, and final, intake of PhD students will start in spring 2023, for students joining in October 2024. The CTP-SAI is an exciting and rewarding programme, and it is a privilege to support the next generation of plant scientists as they start their careers in applied research.

Dr Fiona Leigh is a senior research scientist at NIAB. With over 20 years' experience of characterising genetic diversity of crop plants using molecular markers, Fiona is part of the pre-breeding team, capturing diversity from wheat relatives in order to augment the traits available to the wheat breeding community. She is also the CTP-SAI research lead, co-ordinating the programme with Emma Garfield (G's Growers), the industry lead and overall CTP-SAI Director.

CTP Sustainable Agricultural Innovation

For more information contact Dr Fiona Leigh,CTP-SAI research lead

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www.ctp-sai.org

CTP-SAI

@ctp_sai

Figure 1. The CTP-SAI consortium, led by G's Growers

Figure 2. MDS training in key business skills is provided for students in the CTP-SAI throughout their PhD timeframe

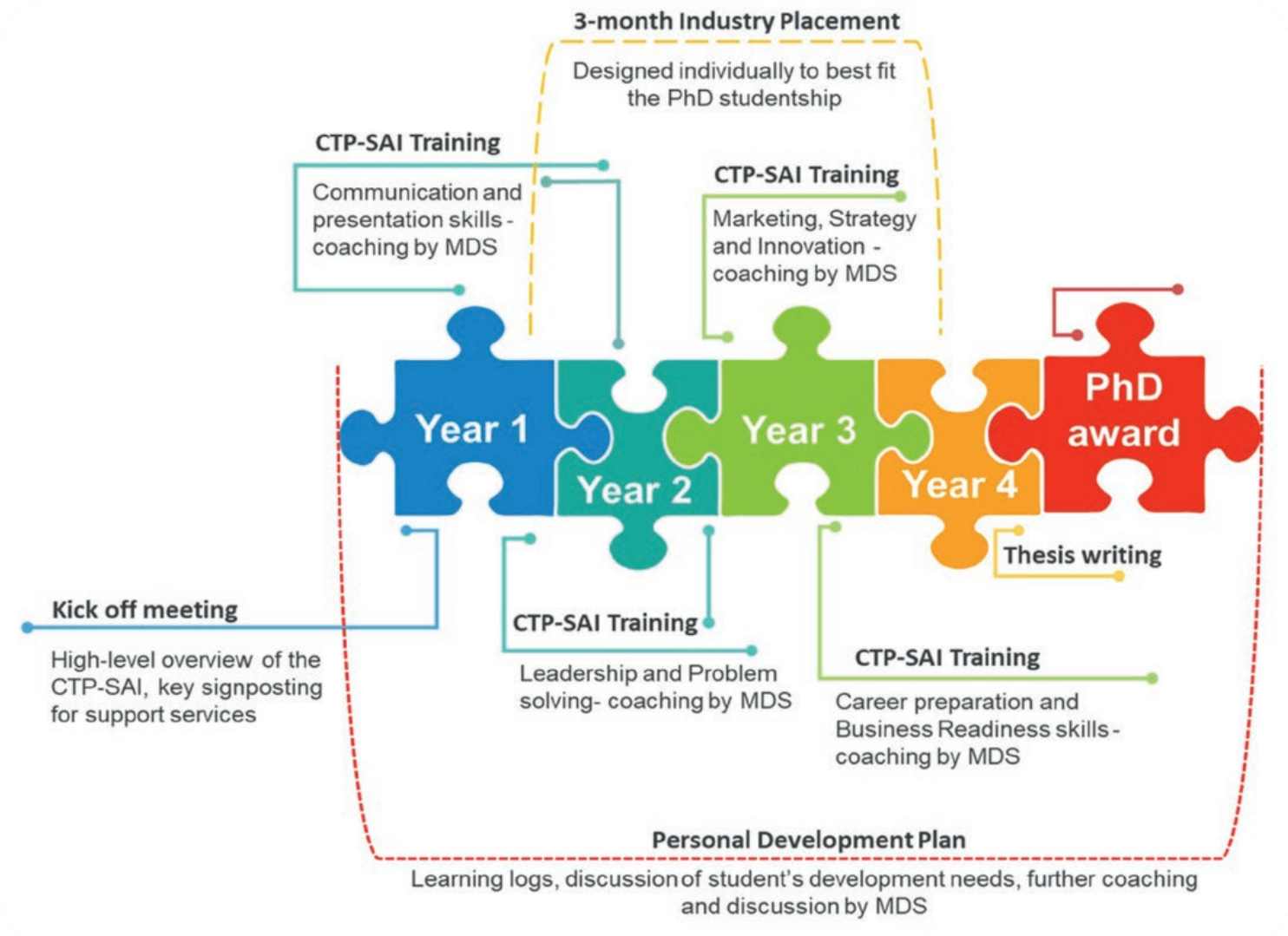

Figure 3. The first cohort of CTP-SAI graduate students at their induction day at NIAB, October 2022

Colin Peters • colin.peters@niab.com

Winter oilseed rape candidate varieties in 2023

As we move forward into the spring and oilseed rape crops are hopefully recovering from the severe frosts that have affected some parts of the country, it is time to look forward to this year's crop of AHDB Recommended List (RL) candidate varieties that farmers may be planting in the summer of 2024.

Colin Peters is NIAB's break crop specialist, providing specialist technical and scientific knowledge on the evaluation, selection and management of crop varieties, focusing on break crops including oilseed rape, linseed, pulses, sugar beet and other minor crops.

There are a few select varieties being grown in consideration for addition to the Recommended List this year. However, several have not fully completed National List testing for variety registration which they have to pass to prove that it is distinct from other varieties as well as 'stable and uniform' with a potential yield benefit over the List's existing varieties. We are unable to publish information about varieties until they have passed National Listing so there are still five varieties to report on in the future in addition to those described in this article.

Clearfield® (CL) oilseed rape is a production system combining hybrid oilseed rape varieties with innovative herbicides. The varieties are genetically resistant to the herbicides meaning that troublesome weeds such as charlock or volunteer plants that were a problem in some areas can be tackled. Using traditional plant breeding methods, varieties are now being bred by a number of different companies giving growers a good choice with yields nearer that of standard varieties.

Miraculix CL (DSV) is the latest Clearfield® variety. It has a UK-wide recommendation with an overall gross output (GO) score of 97%. It is an average height variety with stiff stems and good resistance lodging and also with a high oil content. Fairly early to flower and mature Miraculix CL has very good stem canker resistance although less resistance to light leaf spot. Another positive is its genetic resistance to pod shatter and Turnip Yellow Virus (TuYV).

Pi Pinnacle (Grainseed) is a conventional variety with full UK listing. The variety has a very good GO score of 104% despite an average oil content. It has fairly short stems with very good standing ability and resistance to lodging. It is late flowering but matures medium early, with good resistance to light leaf spot and average resistance to stem canker, but no resistance to pod shatter or TuYV.

Kanzzas (RAGT) is next on the candidate list for the East and West regions. This is a hybrid variety with a very good GO score of 105%, again with an average oil content. It is a fairly tall variety with very good standing ability and resistance to lodging. The variety is fairly late flowering with average maturity date scores and very good resistance to light leaf spot although a bit weaker to stem canker and no resistance to pod shatter or TuYV.

Dolphin (DSV) is listed for the East and West and is a hybrid variety with a very good GO score of 105%, and a high oil content. It is a short variety with excellent resistance to lodging with medium late flowering and maturity. The variety has an average resistance to light leaf spot but very good resistance to stem canker. It also has resistance to TuYV but not pod shatter.

Staff news

Elizabeth wins NIAB staff medal

NIAB's in-house staff award – the Bentley Nelstrop Medal for Enterprise and Innovation – was initiated by former NIAB Trustee Bentley Nelstrop, and celebrates exceptional contribution to innovation and enterprise by an individual or a team from within NIAB.

The 2023 award has been won by Dr Elizabeth Stockdale.

NIAB's Head of Farming Systems and Agronomy Research was nominated for her role in establishing our Future Farming Resilience Fund programme, a major and important new strand to the support NIAB provides to farmers and landowners across the country in the development and resilience of their farming businesses and systems. Elizabeth has also instrumental in delivering farmer and community engagement around Paludiculture; farming on rewetted peat. This is alongside the more conventional farming systems, soils and agronomy research and knowledge exchange that Elizabeth and her team already delivers for growers across the arable, potato and forage crop sector.

NIAB Director of Agronomy Stuart Knight, explained that Elizabeth has embraced, and adapted to, the challenges of delivering new project types with different and demanding development, reporting, and funding requirements. "The projects are strategically important for NIAB, have unlocked new sources of revenue and make good use of the skills and resources that we have, as well as providing new openings at NIAB in the area of farm business support."

Belinda leads NIAB vine and wine

Dr Belinda Kemp has joined NIAB in the new role of oenologist, leading the vine and wine research at our East Malling site. She is already well known to the UK wine industry, bringing 18 years of international experience – most recently as principal scientist in oenology at the Cool Climate Oenology and Viticulture Institute (CCOVI) in Ontario, Canada, and previously in posts in New Zealand and the UK. Belinda joins NIAB at a time when the UK viticulture industry is rapidly expanding and we are excited by the leadership and guidance that she will bring to this new role.

Ros Lloyd • ros.lloyd@niab.com

Putting our plant science into practice this summer

If you haven't attended a NIAB open day or it has just been a while – this year is an ideal opportunity to come along and take a look at the wide range of independent advice and research we carry out, meet our newest members of staff and catch-up with some old faces.

NIAB is renowned for showcasing agricultural innovation and research for growers and agronomists to check out at summer trade events and open days; demonstrating how they can and will be put into practice on farm and the economic and agronomic benefits in their use.

For example, at this year's Cereals Event, in Nottinghamshire on 13th and 14th June, NIAB is showcasing options for more resilient future agricultural systems, with 20 different crops featured on our stand, alongside the popular winter wheat variety and fungicide plots. Visitors can take a look at diverse range of the UK's underutilised and novel crops that may become more popular over the next few years on farm, and discuss crop management options with NIAB specialists and advisors. With five herbal grazing ley mixtures alongside buckwheat, quinoa, grain maize, durum wheat, hybrid rye and triticale growers have the option to view the crops above and below ground in the 20 metre long NIAB *Soil Hole*.

And from peas and beans to lentils and lupins, chickpeas and soya, visitors can also uncover the benefits of protein crops. NIAB's research work on legume crop improvement will be central to the feature as growers can explore the opportunities for crop diversification and lowering inputs on farm and new market prospects as a plant-derived protein source in food and animal feed. This work is also available to discuss on NIAB's stand at the Groundswell Event on 28th and 29th June in Hertfordshire, where we feature our research, advice and information within the principles of regenerative agriculture. NIAB is also the sponsor of the event's Soil Seminar Marquee, with NIAB speakers covering agronomy practices alongside the long-term impact of using direct drilling.

With over 25 years of experience in farming and scientific communications Ros Lloyd is NIAB's Head of Communications. She manages and produces the organisation's PR and communications, conveying to many different audiences all aspects of work carried out by NIAB, through various channels including events, online, social media, publications and press to meet member and stakeholder needs.

NIAB Open Days

But don't worry, our traditional and popular variety demonstration plots tours are still the main feature at many, if not all our events, alongside agronomy advice and opinion from our team of crop specialists with a range of plots covering disease management, nitrogen strategies, soil and rotation management and weed control.

Two specialist events kick off proceedings with a new location for the soil and crop nutrition research open day at our Saxmundham trial site in Suffolk on 1st June, followed by a demonstration of our work into the sustainable management of broad-leaved weeds on 6th June at our Diverse Weeds event at the Cambridge-Hinxton trials site. The regional NIAB Open Days, this year at Cirencester (6th June) and Cambridge-Duxford (8th June) have a more specific focus on practical variety and agronomy demonstrations.

We are also running similar events as part of the Morley Innovation Day, hosted by The Morley Agricultural Foundation on 22nd June and at the Croft Open Day, hosted by Croft Farms alongside our partner ArGrain on 29th June, mixing with research partners, funders and industry, ensuring the latest independent information and advice from a wide range of specialists.

Book your place at our events by logging onto www.niab.com and click on the NIAB Events Hub.

NIAB

Summer Events 2023

FIND US AT KEY INDUSTRY EVENTS

Cereals THE ARABLE EVENT

Tuesday 13 & Wednesday 14 June
THORESBY ESTATE, NOTTINGHAMSHIRE

Groundswell

Wednesday 28 & Thursday 29 June
HITCHIN, HERTFORDSHIRE

FREE AND OPEN-TO-ALL
BOOK YOUR PLACE AT NIAB OPEN DAYS

Featuring variety and agronomy demo plots, advice and research

SAXMUNDHAM • Thursday 1 June
SOILS AND ROTATIONS – SUFFOLK

SOUTH AND WEST • Tuesday 6 June
VARIETIES AND AGRONOMY – CIRENCESTER

CAMBRIDGE • Tuesday 6 June
DIVERSE WEED MANAGEMENT – HINXTON

CAMBRIDGE • Thursday 8 June
VARIETIES AND AGRONOMY – DUXFORD

EAST • Thursday 22 June
VARIETIES AND AGRONOMY – MORLEY

NORTH • Thursday 29 June
VARIETIES AND AGRONOMY – CROFT

Visit niab.com/niab-event-hub for event details and registration

NIAB Agronomy members have exclusive access to additional regional cereal variety and agronomy days at our Sutton Scotney, Taunton, Kingsbridge and Dorset regional trials sites, plus specialist events at Faversham (ryegrass), Hardwick (black-grass) and Corringham (black-grass).

Please check the NIAB Agronomy Membership website for more details, dates and booking.

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Nathan Morris • nathan.morris@niab.com

Homing in on nitrogen and sulphur fertilisation for milling wheat

Dr Nathan Morris is NIAB's farming systems and soils specialist with over 15 years of applied soil and nutrient management experience. He has a strong interest in cropping systems and nutrient interactions and the impact on crop productivity.

UK milling wheat market

UK millers currently use around five million tonnes of home-grown wheat each year, compared with around two million tonnes in the early 1980s. In a typical year, this makes up around 85% of the flour produced by UK millers (UK Flour Millers, Wheat Guide 2022). Achieving quality for end user markets remains paramount for all milling varieties. Hagberg Falling Number, specific weight and protein are key quality characteristics. Each has a significant impact on the final flour quality, the dough consistency (known as rheology) and baking performance of the final loaf. The current target set for protein concentrations is 13% for Group 1 varieties (Figure 1). Recent evidence has identified that achieving this protein specification consistently is difficult in high-yield milling varieties. Farmers often use an additional targeted fertiliser application with extra nitrogen (N) and sometimes also sulphur (S) applied to boost protein of milling varieties. However, there are no new data to support better management of nitrogen or sulphur applications, both rates and timings.

The milling wheat project

NIAB led an AHDB-funded project '*Nitrogen and sulphur fertiliser management to achieve grain protein quality targets of high yielding modern winter milling wheat*'. The study measured the effects of nitrogen and sulphur fertiliser (rate and timing) on grain quality (grain protein, specific weight and Hagberg Falling Number), and provided new data on baking rheology comparing use of ammonium nitrate (AN) or foliar urea as the nitrogen fertiliser. Field trials were undertaken in replicated plots, on a range of soil types, across southern and eastern England and in Scotland, during 2019, 2020 and 2021. The project evaluated a range of nitrogen (N) and sulphur rates and timings on three winter milling wheat varieties including KWS Zyatt (Group 1), KWS Siskin (Group 2) and Skyfall (Group 1) with typical milling specifications (Figure 1). A key feature of this project was to examine the effect that nitrogen and sulphur fertiliser had on grain quality and baking rheology, including test baking bread (Figure 2).

Data from the British Survey of Fertiliser Practice indicated that the average field application rate on milling wheat, averaged over five years (2017-21), was 202 kg N/ha, compared to 177 kg N/ha for non-milling crops. This difference of 24 kg N/ha is less than the additional 40 kg N/ha recommended for milling varieties in the current Nutrient Management Guide (RB209). This difference may arise from several factors beyond less extra N being applied to boost protein of milling varieties; for example, soil conditions (e.g. soil N supplies from previous cropping) or growers' perceptions of yield levels and hence nitrogen demands of modern wheat types may be changing.

Figure 1. Typical specifications for milling wheat (AHDB 2023/24 Recommended List varieties)

	UK Flour Millers Group 1	UK Flour Millers Group 2
Minimum specific weight (kg/hl)	76.0	76.0
Maximum moisture content (%)	15	15
Maximum admix (%)	2	2
Minimum Hagberg Falling Number (HFN, s)	250	250
Protein content (% DM)	13.0	12.5
2023/24 winter wheat RL varieties	Crusoe KWS Zyatt RGT Illustrious Skyfall	KWS Extase KWS Ultimatum KWS Palladium KWS Siskin Mayflower

Nitrogen and sulphur nutrition for milling wheat

There was no real difference between applying extra N early in stem extension, GS 32, or at the end of stem extension (GS 39), unless a dry spring prevented crop N uptake. The amount of extra N applied above RB209 recommended rates is more important than the timing of it. Small increases in grain yields were seen when applying additional AN at GS 39, particularly for the more responsive Group 1 varieties. No yield increase was found where more extra N is applied as foliar urea early in grain development (GS 73); in fact, in some instances applications of foliar urea can cause slight yield reductions. Varieties responded slightly differently to N applications but there was no significant effect on baking quality. N application at GS 73 consistently increased protein to higher levels than earlier applications. Grain protein could be increased where extra N was applied: on average, an additional 40 kg N/ha increased grain protein by 0.5%, an additional 80 kg N/ha increased grain protein by 1.0%, and an additional 120 kg N/ha increased grain protein by 1.3% (Figure 3).

One key finding was that there was no detrimental impact on baking quality when foliar urea was used compared with applications of ammonium nitrate. Where foliar urea was applied with extra N rates of 40 or 80 kg N/ha at GS 73, the gluten had more strength compared with N applied as AN (Figure 4). Flour proteins were also higher where foliar urea had been applied compared with the AN treatments. Late foliar urea applications tended to show a further increase in grain protein of between 0.2 to 0.5% compared to the same rate of AN.

In these trials, there was no significant response to sulphur, probably because most of the sites were not deficient. The addition of sulphur fertiliser to sulphur-deficient wheat grown for flour milling or cereal foods is useful where acrylamide formation can be minimised. There was no requirement to alter current recommendations for sulphur fertilisation, with applications of 50 kg SO_3/ha, where a risk of S deficiency is identified.

The project confirmed that achieving 13% grain protein consistently across sites and seasons using three currently commercially available wheat varieties (KWS Zyatt, KWS Siskin and Skyfall) is difficult. Provided that other quality thresholds (e.g. specific weight and HFN) were achieved, the additional N applied to achieve 12.5% grain protein made little difference to the key parameters relevant to baking rheology. Thus this raises the question as to whether the current requirement of 13% grain protein content for bread-making wheats remains valid, especially given the increasing prices for N fertiliser and the significant impact of N fertiliser use on the carbon footprint of cereal products. Achieving all milling specifications, not just grain protein, is important to ensure grain meets the requirements for the UK's diverse baking industry and retail sectors.

Acknowledgements

This work was funded by AHDB Cereals and Oilseeds. Project number RD-21140040. The final report PR642 '*Achieving milling wheat quality through N and S management*' can be found on the AHDB website. Allied Technical Centre (ATC) for pilot milling and test baking. RAGT Seeds for providing seed and grain quality analysis. Agrii for in-kind contributions and further datasets. KWS UK Ltd, SRUC, Omex, Frontier Agriculture, Hillcourt Farm Research, CF Fertilisers and Compass Agronomy for in-kind contributions.

Figure 2. Test baking to determine the quality of the flour

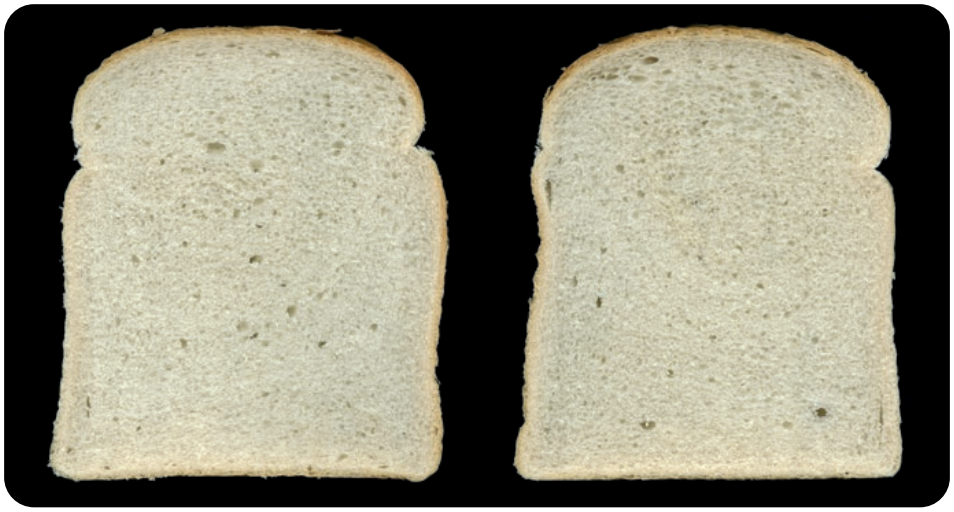

Figure 3. Average effects of extra N on (a) grain yield and (b) grain protein from ten experiments harvested from 2019 to 2021. Additional N was applied as ammonium nitrate granules (AN) or foliar urea in sprays at 20% (w/v)

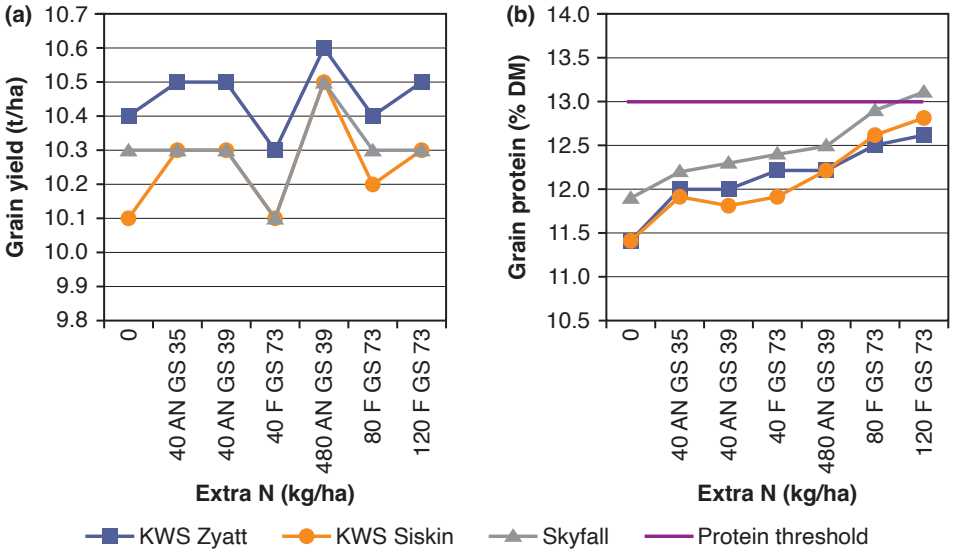

Figure 4. Summary of rheology and test baking parameters for ammonium nitrate and foliar urea treatments

	Rheology				Baking	
	Farinograph	Extensograph				
	Stability time (min)	Resistance (BU)	Extensibility (cm)	R/E	Loaf volume (cm³)	Bread Score
Mean of ammonium nitrate fertiliser trials	3.5	282	16.8	1.7	3818	5.5
Mean of foliar urea fertiliser trials	3.9	320	17.4	1.8	3783	5.5

Will Smith • will.smith@niab.com

Taking off the blinkers – life beyond black-grass

Will Smith is a research agronomist within NIAB's Farming Systems Group, working on the issues of weed management across the agricultural sector. His focus is the evaluation of non-chemical methods of weed control, including efficacy testing, practical integration and the economic effects of these changes in approaches.

If you were to ask a farmer to name a weed, then it is more than likely that the response will be black-grass. This is the weed that has dominated the minds of growers, agronomists and researchers for nearly two decades. Such single-mindedness has seen breakthrough moments for many growers as populations have begun to retreat, with the real problem fields harder to find. The downside of this has been the formation of blind-spots when it comes to other weeds. We will try to re-focus the eyes onto a mix of species that are returning as farming systems change, some species that are adapting to these farming systems to become weeds, and invasive species that might be imported onto farmland.

The return of old foes

Some species rise and fall in prevalence, without ever really going away. The brome family reside here, with reports of the *Bromus* species, rye brome and meadow brome, and the *Anisantha* species, in particular sterile brome, on the rise (Figure 1). A reduction in the intensity of tillage used on farms, most notably where it has been completely removed, is a key factor for the increasing detection of these weeds as the dormancy characteristics enable it to avoid pre-drilling destruction, therefore emerging within the crop. These species do not emerge from depths greater than 15cm and do not persist for more than two years in the seedbank, so the use of tactical ploughing can prevent populations building up to beyond economic thresholds.

Within a wheat crop, control of these species, in particular the *Bromus* species, is achieved with ALS-inhibitor herbicides e.g. mesosulfuron-methyl or pyroxsulam, applied in the spring, whilst propyzamide is key in oilseed rape. Resistance to ALS-inhibitors has been detected in all UK brome species that infest arable crops. However, it does not exist at the same frequency as resistance as in other grass-weeds. If you have seen poor control from any of these actives then a resistance test is useful tool to confirm the status of the population.

In total contrast, other growers are taking lessons from black-grass management, and have reduced the use of ALS components in a weed management programme – whether by growing more competitive crops e.g. winter barley, which has no ALS registration or by deliberating not using them as they are deemed ineffective on black-grass. If insufficient consideration has been given to the role the ALS has played in controlling other species then it is possible weeds have been left uncontrolled, and therefore begun to build-up in density.

Species becoming weeds

The hedgerows and field margins are full of species that rarely make it as far as "weed" status. However, some that have over-come this hurdle have been the closely related pair of bur chervil (*Anthriscus caucalis*) and Poison hemlock (*Conium maculatum*) and the grass-weed Rat's Tail Fescue (*Vulpia myuros*). All of these species have reached near ubiquity within the UK landscape, including in non-productive areas of farms, and changes within the field environment has encouraged them as weeds.

Bur chervil (Figure 2) is often left uncontrolled in oilseed rape crops as growers have reduced the use of pre-emergence herbicides in what has become a risky crop to establish. It is then appearing in the cereal portion of the rotation, avoiding the majority of pre-emergence herbicides. The sulfonylurea herbicides such as metsulfuron-methyl remain effective if applied in early spring. Poison hemlock is a poisonous species that is being allowed to reproduce in un-mown hedgerows or field margins, which can adapt to no-till fields due to its biennial characteristic. This weed is a particular risk in systems that incorporate livestock.

Rat's tail fescue is an annual grass-weed that is being increasingly detected in no-till situations, where a shallow rooting system and small seeds are more advantageous. It is naturally tolerant of ACC-ase inhibitors (-fops, -dims and -dens). Sufficient control can be achieved with flufenacet as a pre-emergence or peri-emergence, whilst ALS-chemistry is

Figure 1. Bromes in the UK: (l-r) Great brome, Sterile brome (barren brome), Rye brome, Meadow brome, Soft brome

highly effective if applied in the autumn, However, delaying applications until the spring can bring significant challenges. Typically this weed is being found where grass-weeds are not currently a significant concern so pre-emergence programmes are not being adequately focussed. The added difficulty for control is the very thin, slender leaves which can be problematic for the delivering of herbicides, including glyphosate.

Invasive species brought in by system change

The use of cover crops, catch crops or environmental areas, to achieve full-season ground cover, biodiversity benefits or improvements in soil health is continually expanding in market size, and as the introduction of the SFI begins this market is predicted to grow. Despite the noted benefits, these provide the opportunity for other species to be imported into the systems, potentially establishing themselves as weeds. Individual cover crop components that re-establish into the following crops, such as phacelia, radish or buckwheat, are generally harmless and easily controlled either by cold temperatures, or by herbicides actives such as metsulfuron-methyl and tribenuron-methyl.

Figure 2. Bur chervil

Far less innocuous are species such barnyard grass (*Echinochloa crus-galli*) or dodder (*Cuscuta campestris*). Barnyard grass is a global weed which has developed resistance to key herbicides including nicosulfuron and glyphosate. Such status means that its presence in UK farmland, where infestations are likely to be in later sown spring crops, is incredibly worrying. It has been found as a contaminant of game bird mixes, where it is mistaken for millet. Dodder is a parasitic weed, whose hosts are leguminous species such as clover or lucerne. Although it is not anticipated to be a wide-spread issue, the only control measure is to stop growing the host crop, it could be highly problematic for growers who rely upon legumes in the system for crop nutrition. This is another species that is likely to be imported within alternative seed mixes. NIAB is collecting samples for analysis to determine the extent to which this is an issue.

One of the first steps of effective weed management is the identification of the weed early in the season, so getting used to spotting the weeds discussed here is really important. This can ensure that the most appropriate control measures are applied in the most timely manner.

NIAB herbicide resistance testing service

For more information visit niab.com and search for 'herbicide resistance testing'

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