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Landmark

AI-driven variety ID

Drone-based aerial phenotyping platform experience leads to variety ID using artificial intelligence

In this Issue

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Weathering the perfect storm

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.

It is now confirmed, 2023 was the warmest year on record with average global temperatures around 1.5°C above pre-industrial levels. In the past few years we have seen extremes of weather which are directly impacting on crop productivity. This winter has seen widespread flooding, could next summer bring another devastating drought? That would not be a surprise. These changes are also creating the ideal conditions for the emergence of new pests and diseases.

In 2009, Professor Sir John Beddington predicted a "perfect storm" of conditions that would lead to food shortages by 2030. Launching the Foresight report on global food security, he said that in Britain food shortages would drive increased imports, and forecast that the country will become less able to grow crops as higher temperatures become the norm. We should also add today to these conditions the impact of wars and human conflict.

Yet Professor Beddington also offered optimism that science and innovation could come up with solutions to weather the 'perfect storm' of food shortages, water scarcity and depleted energy resources. He said: "We need investment in science and technology, and all the other ways of treating very seriously these major problems. 2030 is not very far away."

Inclusion of food and agriculture in the COP28 discussions in December 2023 also served to highlight the critical role of agricultural innovations in achieving food security and climate goals sustainably.

It was also in 2023 that the Genetic Technology (Precision Breeding) Act received Royal Assent. This Act aims to modernise crop and livestock breeding, and as such represents an important milestone, the first time in decades that new legislation in the UK has been brought forward which seeks to enable, rather than restrict, the use of advanced genetics for agriculture. It was also the year in which the potential for artificial

intelligence (AI) to do good and bad was established in the public debate. This issue of *Landmark* explains how NIAB has invested in AI to help further our ability to collect and curate data.

Implementation of the Sustainable Farming Incentives (SFI), the new farming payments introduced by Defra as part of the transition away from the basic payment system, includes support for interventions that reduce the use of fertilisers and other inputs with the objective of delivering environmental aims such as biodiversity net gains whilst maintaining current yield levels. But, will this the case?

This was one of the questions put to Secretary of State for Environment, Food and Rural Affairs Steve Barclay following his announcement of changes to the SFI scheme at the Oxford Farming Conference in early January 2024, including higher payment rates and fifty new SFI actions. He also announced new scheme funding for precision farming and the roll out of new technology.

These announcements are clearly designed to increase farmer uptake of the new payment schemes, which to date has been low. And the sentiment in the room was that it represents progress in the right direction but a key question remains: without proper assessment of the base line and in the absence of metrics to monitor progress over time, how can we assess the impact of these interventions? These points need addressing.

The farming conferences in Oxford, original and 'Real', are a great warm up to kick start the year after the Christmas Break. As a newly appointed Director of the Oxford Farming Conference, I had the opportunity to experience the behind-the-scenes preparation that goes into delivering this event, and it does not let you down. The agenda for this year's meeting featured presentations by the Secretary of State, his opposition counterparts, and a range of speakers inspired by the theme of meeting: the power of diversity.

The Oxford Farming Conference also commissioned a report entitled: "Is our UK supply chain broken?" My interpretation is that it is not broken, but the UK's food system is under considerable stress. The growers are taking the lion's share of the risks in farming under challenging conditions.

Secretary of State Steve Barclay at the 2024 Oxford Farming Conference

These risks are diverse and range from the uncertainty of the economic climate to the erratic patterns of the weather.

The report concludes that we are living an era marked by change and volatility. Taking risks is just a consequence of that. In the risk vs rewards equation, however, the growers see little in return.

A recent survey of NIAB's members confirmed that farmers would welcome more information to help them manage these risks, including access to consistent metrics and reliable assessments of the impact of their management decisions.

This is particularly relevant in the context of the increasing value chain interest in sourcing products from regenerative agriculture systems. Without the backing of solid scientific research, there are concerns that some of the policies and practices involved could negatively impact yields and domestic food production. A reduction in UK farm output would not only increase our dependence on food imports but could also result in potentially more harmful environmental impacts elsewhere.

NIAB has consistently sought to deliver the scientific research and evidence needed by farmers and growers to support sustainable and efficient crop production systems while at the same time mitigating and adapting to climate change.

As an example, this issue of NIAB *Landmark* includes an update on the Centre for High Carbon Capture Cropping (CHCx3), a large consortium led by NIAB that aims to help UK farmers build farm resilience through diversified cropping and offsetting of emissions. Input-efficient crops that can increase carbon capture will help farming and associated industries address climate change, but there must be confidence in achieving profitable and sustainable outcomes.

We should expect a warmer 2024, but also further advances in the tools we have at our disposal to address the associated challenges. We need to do more to reduce the emissions from agriculture, increase crop yields and at the same time adapt to climate change. Let science and innovation help us resolve today the problems of tomorrow!

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New cereal varieties for 2024

The 2024/25 AHDB Recommended Lists, published in December 2023, see a range of very useful new varieties, many of which are likely to find a place on farm over the next few years. With 2023 proving another difficult year for crops with high Septoria pressure and more lodging than we have seen for years, resilience and reliability remain at the forefront of people's requirements. Hopefully, many of these new varieties will help address concerns and minimise risk wherever possible.

Clare Leaman has worked in variety evaluation at NIAB for nearly 30 years. For the majority of this time Clare 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

Five new winter wheats were added to the new AHDB Recommended List. **SY Cheer** (Syngenta) is a provisional Group 1 variety, the first since 2017. With testing ongoing, the Group 1 classification will be confirmed by UK Flour Millers in the spring. Whilst SY Cheer does not bring an improvement in treated yield, slipping in between KWS Zyatt and Skyfall, it does bring a good untreated yield and a vastly improved yellow rust rating of 7 compared with the 3 of both aforementioned varieties. With a decent 6 for both brown rust and Septoria it should prove much easier to manage disease-wise out on farm. With a high specific weight and Hagberg as well as a protein content second only to that of Crusoe, SY Cheer looks set to help address some of the concerns growers have had in this sector over the last few years.

The Group 3 sector has seen a stream of new varieties over the last four or five years but none of them have made an impact and the group has been seen as particularly uninspiring. That is all about to change with the introduction of **Bamford** (Elsoms). Bamford provides a huge step forward in yield, being equal to the best feed varieties both treated and untreated and well above the current Group 3 varieties. It has a good set of disease resistances and relatively good straw strength. As well as being competitive as a feed variety it is suitable for all Group 3 markets so can offer wide market opportunities wherever you are in the country. It has been consistently high yielding across all situations and drilling dates. The only slight notes of caution are that in 2023 it did have a couple of sites showing higher levels of yellow rust infection as well as some lodging so it would pay not be complacent with disease monitoring or straw management, especially until more experience of this promising new variety is gained.

The other new addition to this group is **Almara** (Senova) with a recommendation for the North where it has yielded well. It has good resistance to yellow rust, a 6 for Septoria and resistance to orange wheat blossom midge. It too offers access to all the main Group 3 markets and seems happiest on lighter soils.

Blackstone (Elsoms) is a new soft feed addition. Whilst yields do not match those of LG Redwald the variety's good yellow rust resistance, stiff straw and good specific weight certainly address some concerns, and combined with good market options, a wide drilling window and orange wheat blossom midge resistance, it is certainly not without merit.

Finally, we have **LG Beowulf** (Limagrain), a hard feed wheat. LG Beowulf offers a top yield both treated and untreated, good disease resistance as well as stiff straw. This combined with a good specific weight means that it addresses many of the concerns that are raised about other top yielding varieties and will help growers maximise yield while minimising risk. It has been consistently high yielding across years, situations and drilling dates and will undoubtedly and rightly be in demand.

So out of the five new winter wheat entries we have three exciting varieties which have an obvious role going forward and two that might not be headliners as such, but still have plenty of merit. All in all a good year for winter wheat.

The spring wheat AHDB Recommended List sees two new additions; a quality wheat and a feed. **WPB Mylo** (LSPB) joins Group 2 with a high yield, good disease resistance and good grain quality. **SEW-19-3003SW** (Cope Seeds), with a future name of Everlong, is a very high yielding feed wheat with good disease resistance and early maturity. Limited data has shown some weakness of straw so decent straw management may well be required.

Barley

Two new varieties grace the AHDB Winter Barley Recommended list. **LG Capitol** (Limagrain) is a high-yielding two-row feed that sits up alongside top yielder LG Caravelle. It offers a moderate to good disease profile which produces a high untreated yield. Relatively stiff straw and a good specific weight combine to make a low-risk, high-output variety that limited data suggests is particularly suited to heavier soils.

SY Buzzard (Syngenta) is a six-row hybrid and joins KWS Feeris in offering barley yellow dwarf virus (BYDV) tolerance; a very useful trait to have access to, especially in higher risk areas. Its yield is below the top hybrid varieties but is combined with a good to moderate disease profile, stiff straw, and a good specific weight. Another useful tool to manage risk sustainably.

Another new addition to the List is the information regarding Barley Yellow Mosaic Virus (BaYMV) strain 2. 2023 saw widespread virus infection in resistant varieties and the most likely explanation is the spread of strain 2. Most varieties only have resistance to strain 1 with Valerie being the only recommended variety to offer resistance to both.

There are six newly recommended spring barleys, all currently undergoing end-user testing with three brewing types – **Bounty** (Agrovista), **NOS Gambit** (Senova), and **LG Aquarius** (Limagrain), two dual purpose – **Belter** (Agrii) and **Olsen** (Limagrain) and one distilling – **NOS Munro** (Senova). All offer competitive yields but since the quality is key, growers are advised to wait until the end use value is confirmed.

Oats

The Winter Oat Recommended List has no new additions this year with the choice going forward remaining unchanged.

The Spring Oat List, however, sees one new addition and one new described variety. **Asterion** (Saaten Union) is a conventional husked oat offering a high yield both treated and untreated. It has good mildew resistance, moderate resistance to crown rust and tall, relatively stiff straw. The good grain quality characteristics will hopefully be useful to millers and provide wider market opportunities.

Ovation (Senova) is a new naked oat with a moderate treated yield. Improved disease resistance leads to a better untreated yield and its early maturity may prove useful.

Overall, a good year for cereal varieties with many of the new additions likely to make a very positive contribution on farm in the next few years. As always there is a lot still to learn about them and if you have any of them currently in the ground, watch them carefully, treat them accordingly and hopefully you will soon be getting the best from them.

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New break crop varieties for 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.

PULSES

The Processors and Growers Research Organisation (PGRO) Descriptive List for 2024 has added seven new combining pea varieties this year, and two winter bean varieties. There are three new spring varieties and at the time of writing, there is another one which may be added to the List later. Chocolate spot assessments have now also been added to the winter beans List.

Winter beans

LG Arctic (Limagrain UK) is a new winter bean variety, it has a yield of 104%, and is fairly late maturing. Although a little weak on rust, it does have the joint highest downy mildew rating of 6. It is a slightly tall variety which stands well despite being somewhat late to mature. **Ninja** (Senova) is the other new winter bean. It joins with a lower yield of 98% but is the earliest maturing variety on the List. It is also short strawed, but susceptible to downy mildew although it does have a high protein content of 27.3%. Senova's existing Vespa and Vincent winter bean varieties remain at the top of the List, with yields of 109% and 107% respectively. These two varieties also have the best chocolate spot scores.

Spring beans

Three new varieties – **Synergy** (Saaten Union), **Navara** (Senova) and **LG Hawk** (Limagrain UK) – have now been added to the 2024 Descriptive List. Synergy is a high-yielding spring bean (107%) and has performed consistently in recent, somewhat difficult years. A short variety with very good standing ability that matures fairly early Synergy is, however, moderately susceptible to rust and very susceptible to downy mildew. A high protein content, together with the fact it is a low-vicine/low-convicine variety, makes Synergy marketable with a general suitability for the premium export market in addition to the target end-use in monogastric nutrition.

Navara has very good yields (106%), and is a short variety with very good standing ability that matures fairly late. It is, however, moderately susceptible to downy mildew but has moderately good resistance to rust. LG Hawk has moderate yields, is early maturing but is susceptible to downy mildew.

Three other varieties were also added to the Descriptive List in Spring 2023, after the 2023 List was originally published in Autumn 2022. **Futura** (Limagrain UK), another low-vicine/low-convicine variety, yields well at 104%. It matures early but is susceptible to rust and downy mildew. **Genius** (Limagrain UK) was added as the highest yielding variety with a yield of 108%. It has a short straw length, good standing ability, is moderately susceptible to downy mildew and susceptible to rust. And finally, **LG Stego** (Limagrain UK) yields well at 105%, is medium late to mature, moderately susceptible to rust and susceptible to downy mildew.

Peas

There is a new 'pink pea' variety! **Flamingo** has the lowest yield on the DL (78%) but is aimed at specialist markets with seed being distributed in the UK by Cope Seeds and Grain. Seeds Director Gemma Clarke suggests that its unique pink colour remains even after cooking, which presents great human consumption market potential. It should be interesting to watch Flamingo in the marketplace as, alongside its lower yield, it is also late maturing with suspect standing ability. It does have good downy mildew resistance so, with the right financial incentive and the right grower, it could be a great and possibly rewarding challenge.

There are three new yellow peas – **Concerto** (LSPB), **Batist** (Senova) and **KWS Flam** (KWS). Concerto, the highest yielding pea on the List with a yield of 115%, has fairly short straw with good standing ability and good downy mildew resistance. It does have a very large grain size but with below average protein content. Batist has joined the List just below Concerto at 113%. It has tall plants with good standing ability and moderately good downy mildew resistance. KWS Flam, another new, good yielding variety at 110%, is a smaller seed variety, with a medium early maturity date, taller straw with good standing ability, average downy mildew resistance but is also susceptible to powdery mildew.

The two new green peas, **Shazam** (Senova) and **Reacher** (IAR Agri) join the Descriptive List at the lower end of the yields in the group. Shazam, with a yield of 101%, is fairly late maturing but with good standing ability despite having the joint longest straw on the List, and a moderate resistance to downy mildew. Reacher, at 97% yield, is a bit shorter but with low standing ability. However, it is highly resistant to powdery mildew, with a good level of resistance to downy mildew. Reacher also has some genetic resistance to mosaic viruses.

The new variety **Vision** (Elsoms) becomes the top-yielding marrowfat with a yield of 100% and has the best downy mildew rating for any marrowfat pea at 7.

OILSEEDS

Oilseed rape

There are four hybrids, one conventional and one Clearfield® variety added to the 2024/25 AHDB Winter Oilseed Rape Recommended List, plus a change in presentation with the addition of a section specifically for regional rankings (East/West and North). A verticillium resistance status has also been added this year with the varieties where there is available information scored as MR = moderately resistant, I = intermediate, and S = susceptible.

So, topping the List, there are three new Limagrain varieties – **LG Armada**, **LG Academic** and **LG Adeline**. LG Adeline was not fully added on first publication of the RLs in November 2023, but is expected to be included by January 2024, provided no representations are received. All of these follow on in the recent tradition of Aurelia and Ambassador, providing a solid and reliable base. These hybrid varieties are clearly strong upgrades, and all of these carry the mark of the Limagrain 'stem health' screen which scores against phoma, light leaf spot and verticillium.

LG Armada heads up the List at 107% gross output. With full genetic resistance of pod shatter and TuYV, it also has the highest oil content of this new batch at 45.5% which helps boost the gross output figure. All three of the new Limagrain varieties have the same disease resistance profile; a good resistance to light leaf spot (7), with a little less resistance when it comes to phoma where they all score a 6. It is worth noting that several other breeders have stated that they are now introducing new genetics into their varieties to bolster the RLM 7 gene that has been used for many years. LG Armada also does have a shorter flowering window than the other two which may help with sclerotinia control, depending on the weather. Of these three varieties, LG Adeline has produced a slightly better gross output in the North.

Also new on the List is **Dolphin** (DSV), a very good variety, with better stem canker resistance than the three new Limagrain varieties, with DSV boasting RLM7+ genetics on its website. Dolphin does not have pod shatter resistance, but DSV suggests that it does have their new 'Harvest Max' protection traits, which gives its varieties the maximum protection against harvest challenges.

It is good to see a new conventional variety with **Pi Pinnacle** from Grainseed placed as the highest yielding conventional (although only just above Tom). It has good resistance to light leaf spot but is weak on stem canker. It is later flowering but matures at the same time as the majority of the conventional varieties. There is also a new Clearfield® variety – **Miraculix CL** from DSV. This is another strong variety from the DSV stable, mainly targeted to the North. It has TuYV and pod shatter resistance and, like Matrix CL and Beatrix CL, it is a very good variety. It is not great on light leaf spot resistance but has good stem canker resistance and a high oil content.

Spring linseed

There are two new varieties on the AHDB Spring Linseed Descriptive List 2024. **Skylark** (United Oilseeds) heads the List yield-wise with 109%. It is a brown seeded variety with short plants and matures early despite flowering late. The second variety, **Richess** (Premium Crops), has a moderate yield of 97% and matures very early.

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Innovating for a profitable fruit sector

NIAB is using cutting-edge research techniques to offer a lifeline for a fruit growing sector under increasing threat from rising costs. The innovations being developed in genetics and pests and disease management could also make our food production systems more sustainable.

The UK-fruit sector is under growing pressure, from squeezed profit margins due to rising production costs, limited access to affordable labour, and strains in the supply chain. British Apples and Pears Ltd, an industry membership organisation, reported that almost a third of new fruit trees expected to be planted in 2023 were cancelled due to rising costs. This equates to almost 500,000 new trees, which replenish older less productive fruit trees.

Growing varieties that can help improve profitability is one way that growers can make their businesses more resilient to market fluctuations. Whether by producing higher yields, being more resistant to pest and disease, or being more appealing to consumers to demand higher prices. However, bringing new varieties to market is not a quick process.

Thanks to funding from Growing Kent & Medway, NIAB in East Malling is working closely with the fruit industry on several projects to develop new techniques to improve fruit breeding and production.

Fast-tracking apple breeding

Plant-breeder and geneticist, Dr Amanda Karlstrom, is working with Worldwide Fruit Ltd on developing a faster route to market for new, more diseases-resistant apple varieties. Worldwide Fruit is one of the UK's largest grader, packer, storer, marketer, and distributor of UK pome fruits and suppliers to all the major UK supermarkets.

New, premium apple varieties tend to have a significantly higher retail value and therefore offer better profit margins for growers. Introducing new varieties is therefore crucial for the future sustainability of the apple industry. However, many of the new varieties introduced to the UK market are susceptible to plant diseases such as apple scab, powdery mildew, or European canker. These are three apple diseases that are highly prevalent in the UK, which has led to increased disease control measures.

Scab resistance has been successfully incorporated into worldwide traditional breeding programmes as it is influenced by a single gene. Although several major resistance genes are known for powdery mildew, the disease is not as common in other apple-growing regions outside of the UK and so has not been prioritised as widely as scab resistance. Resistance to canker is linked to more than one gene and has been underutilised in breeding programmes. As a result, there are very few commercial varieties with combined resistance to all three diseases.

Lauren Colagiovanni joined NIAB in 2021 as the Senior Communications Manager for Growing Kent & Medway. Prior to working at NIAB, Lauren led the AHDB Horticulture communication team. She has over 20 years' experience in marketing and communication roles at large organisations including BBC and ITV.

As apple breeding programmes traditionally take 25 years to produce new varieties for the market, the industry is particularly vulnerable to new threats and the limited availability of effective plant protection products.

Dr Karlstrom's research aims to develop modern methods to shorten the breeding cycle and find a faster route to market for new, more disease-resistant varieties. Her research will explore three methods; genomic selection, molecular marker-trait associations, and speed breeding.

Figure 1. Multi-resistant apple varieties which meet industry and consumer demand in a significantly reduced time frame could be produced using speed breeding

Genome selection

Genomic selection is a form of marker-assisted selection. This means that regions of DNA that have been linked with specific plant characteristics (i.e. disease resistance) can be used to select plant seedlings that have a higher probability of containing the disease resistance that is being selected for. This breeding method has revolutionised animal and plant breeding and is particularly useful for characteristics influenced by more than one gene. However, genomic selection has not been widely adopted in apple breeding. The NIAB project will evaluate prediction models for how resistant varieties will be to European Canker.

Speed breeding

Speed breeding is a tool that manipulates the environmental growth conditions to accelerate plant development. This results in shorter cycles to develop new generations of plants meaning multiple traits can be incorporated into a single variety faster than using conventional breeding. Integrated with marker-based selection methods, this could produce multi-resistant apple varieties which meet industry and consumer demand in a significantly reduced time frame. The project will use a combination of changing the daily light levels, plant hormones, and growth regulators to manipulate plant development and seed dormancy in apple crops (Figure 1).

Turning over a new leaf

Breeding strawberry plants with better shape and structure is critical for profitable production for UK-growers. Strawberry crops with well-balanced architecture, or the way the plant grows, could reduce production costs by more than 10%. Influencing factors include how many leaves the plant produces, how the leaves are positioned, and how the fruit and flowers are displayed. This impacts how many berries are produced and how sweet the fruit is. Dense canopies can also lead to a greater risk of disease or pest infestations. Bushy plants also make picking berries much slower as more time is spent searching for ripe berries.

The traits involved in breeding good strawberry plant architecture though are complex, so the process is difficult. Professor Dan Sargent, Head of Plant Genetics at NIAB, is working with Edward Vinson to help breed plants with improved plant architecture. Edward Vinson Ltd has been growing fruit for over 150 years and is a leading supplier of soft fruit to UK supermarkets, as well as running a successful breeding programme.

Machine-learning technologies

This project will aim to develop molecular markers to help breed new strawberry varieties. It will use cutting-edge machine-learning technologies to capture data on plant architecture. This data, along with information about the DNA of the strawberry plants, will be used to develop tools to breed strawberries with better plant architecture. The project outcomes will lead to the development of superior strawberry varieties for the UK that are easier to manage and more efficient to pick, thereby supporting a healthier profit margin for growers.

Integrated pest management strategies

Modern varieties are of course an important element of a growers' toolbox. Creating successful integrated pest management strategies to propagate and grow healthy, disease and pest-free plants is also critical to profitable production.

Three NIAB-led research projects were funded by Growing Kent & Medway's Collaborative R&D grants. Up to £350,000 was awarded through a competitive process for projects that supported the transition to net-zero carbon emissions and improved productivity and sustainability in horticultural and plant-based food and drink production.

NIAB entomologist, Dr Francis Wamonje is working with Rumwood Green Farm to develop and test a biocontrol programme to control large raspberry aphid, using parasitoids and natural predators (Figure 2). Recoir is working with Dr Louisa Robinson Boyer, Felicidad Fernandez and Dr Matevz Papp-Rupar at NIAB to use beneficial microbes to grow vigorous planting material to support UK-propagated raspberry crops.

Working with Overland Farm, Dr Papp-Rupar and Dr Flora O'Brien will be looking at how to reduce the risk of diseases in recycled coir substrates. In turn, reducing the high carbon footprint of shipping virgin coir, and reducing costs for growers (Figure 3).

Growing Kent & Medway has awarded over £2.4 million through this funding scheme over two rounds to encourage innovation through business and academic collaboration, attracting over £800,000 of additional industry investment. To find out more about Growing Kent & Medway funding, visit growingkentandmedway.com.

Figure 2. NIAB is developing and testing a biocontrol programme to control large raspberry aphid

Figure 3. Raspberry roots developing well in coir-reduced substrates

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An innovative approach to hybrid wheat breeding

Future global food security will require new approaches to ensure that crop production is maintained given finite arable land availability, the desire to reduce crop inputs and the challenges presented by a changing climate. One technology to improve wheat yields and overall crop resilience is an F1 hybrid plant breeding system.

Hybrid breeding is a technique used to develop new crop varieties with desirable traits by crossing two genetically different parental lines together and enhancing traits like yield, climate resilience, disease resistance, and other agronomically important characteristics. Hybrids exploit the poorly-understood phenomenon of heterosis, or hybrid vigour, in which a hybrid can significantly outperform both of its parents.

The application of heterosis has produced tremendous global economic benefits in established hybrid crops like maize and rice. However, this has been less successful with wheat, where less than 1% of the global area is currently planted with hybrids. This is mainly due to the challenges associated with field-scale F1 hybrid wheat seed production, which requires controlled cross-pollination to produce the hybrid seed for planting. Adapting wheat, a self-pollinating crop, to a hybrid production system requires a means of preventing self-pollination on the seed-bearing maternal plants, so that they can be fertilised by pollen from the paternal plants to set F1 seed. The resulting F1 crop planted by the farmer must be fully self-fertile to ensure maximum yield. Nonetheless, the potential for higher yields and better performance makes hybrid breeding an attractive target for wheat improvement programmes.

For example, our colleague Yeorgia Argirou recently completed her PhD on the potential of NIAB pre-breeding material for F1 hybrid wheat breeding. She created several experimental F1s based on material from NIAB and plant breeder KWS, which were tested in four locations across Europe over two years of trials, identifying promising leads for further work.

Despite the high levels of interest, European F1 hybrid wheat varieties have only been commercially available from the France-based breeder, ASUR. However, other companies including BASF, Bayer, Corteva, Elsoms, KWS, Limagrain, RAGT and Syngenta are known to be developing hybrid wheat.

Two hybrid breeding systems are currently used in wheat. The first, exemplified by ASUR, uses a chemical hybridising agent (CHA) to inhibit normal pollen production and thus prevent self-pollination at flowering. Seed production crops are planted with alternate strips of male parent (for pollen production) and female parent (for F1 seed production), with only the female strips sprayed with CHA (Figure 1). Any wheat line can be used as a male-sterile female parent, although they often differ in their sensitivity to CHA, and any line can be used as a male. However, full sterility requires CHA application to be timed perfectly during a narrow developmental window in late spring, and when weather and soil conditions are benign. There are also concerns regarding the ongoing approval of CHAs for field-scale application.

The second system is cytoplasmic male sterility (CMS), which is the basis of F1 hybrids in several other crops such as winter barley and oilseed rape. Here, the CMS female line is male-sterile (meaning that a self-fertile 'maintainer' version of the female is also required to ensure ongoing female production), while the male must carry dominant 'restorer' genes to restore full fertility in the resulting F1 crop. However, restorer genes often originate from unadapted lines and can bring unwanted deleterious effects with them alongside fertility restoration.

A new alternative is a 'genic' system based on recessive male-sterility, which allows any normal wheat to be used as a male/pollinator for the final F1. This overcomes the breeding issues associated with CMS systems as the hybrid male can simply be selected to increase desirable traits. A remaining challenge is the lack of an efficient sterility system to block self-pollination, combined with the need

Dr Matthew Milner was a senior scientist and part of the NIAB Crop Transformation team until December 2023.

Research lead in Crop Genetic Resources Dr Phil Howell has played a pivotal role in NIAB's crop improvement work since 2007, working on major pre-breeding projects including the flagship wheat resynthesis programme. He has over 30 years' experience of crop genetics and breeding in broadacre 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.

Figure 1. Small scale experimental CHA F1 hybrid production block, NIAB 2019. Plots of female (F) lines are planted in rows, interspersed with rows of a male pollinator line (M). Female rows only were sprayed with CHA using a contained sprayer to prevent any drift onto male rows. After application, but prior to anthesis, random female ears were bagged to assess seed set and monitor CHA efficacy (no seed set indicates male-sterility and thus effective CHA application). F1 seed, harvested from female plots, results from the pollination of females (F) by the male line (M)

for a 'maintainer line' to pollinate and multiply the female line without restoring its fertility.

A genic system will most likely require some optimisation to help track the inheritance of alleles required for male sterility and restored fertility. Wheat has a complex hexaploid genome, with many genes present in multiple copies each tracing wheat's ancestral species, meaning that advances in understanding gene function and technology adaptation have often lagged behind other crops with simpler genomes. NIAB has been working to identify and characterise genes involved in wheat pollen formation, viability and pollen tube growth which could be used in a hybrid breeding system. This has been in conjunction with Anthony Keeling of Elsoms Developments (a sister company of Elsoms Seeds) who has fully-funded work over the past ten years or more (Figure 2).

Figure 2. Dr Matt Milner and Anthony Keeling inspect hybrid wheat embryos in the growth rooms at NIAB

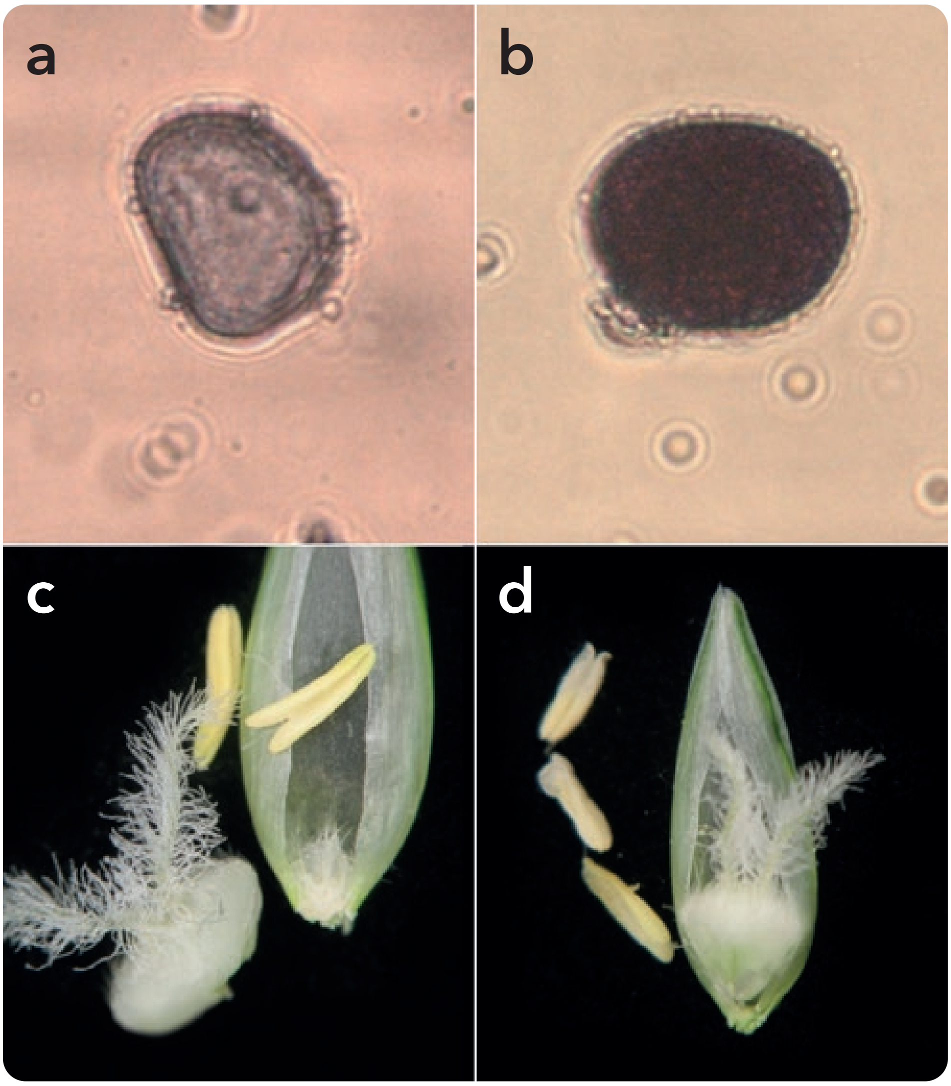
Three different steps are needed for the Elsoms/NIAB hybrid system to work. The first stage of experiments was to create male-sterile plants in which pollen formation was disrupted, but female fertility remained unaffected. This work targeted genes involved in early stages of pollen formation, as these show simpler inheritance, with clear phenotypes including gaping flowers and poor seed set (Figure 3). As many male-fertility/sterility genes are highly conserved between plant species, knowledge of genes from other species can translate to understanding their function and relevance in wheat.

However, not all genes involved in pollen formation are suitable for use in a hybrid wheat breeding system, as often one functional allele is insufficient to maintain or restore full fertility. For example, the Ms26 gene is present on all three of wheat's ancestral genomes: lines with all six sterile alleles are fully male-sterile, but those with just one fertile allele show only partial fertility, and two fertile alleles are required to show the same fertility as normal plants. This makes Ms26 unsuitable for a standard maintainer/male sterile system. A different gene called Ms1 is also found at three locations in the wheat genome, but in most modern wheats it is only functional at one of these and has expressed full fertility from just one allele making it an attractive gene for a hybrid system.

The second big hurdle for a genic hybrid system is a gene expressed in the pollen itself. Such a gene is much harder to identify because true-breeding male-sterility mutations, by definition, are never observed. Genes which show this type of inheritance pattern are often involved in later aspects of pollen function such as pollen tube growth with the loss of function rendering the pollen non-viable, and tend to be less conserved than genes involved in pollen formation. Only a few examples have been previously identified; we have identified one such gene in wheat which clearly shows the disrupted inheritance expected and only requires one functional allele per pollen grain to maintain full fertility and seed set.

The third, and final, component required for our hybrid system is the ability to track the first pollen-development gene to maintain the system for hybrid production. This usually involves some type of visible trait, so that seeds can be sorted to ensure a sterile plant in an F1 seed production field. Such systems include grain aleurone pigmentation genes; optical seed sorting machines can quickly process mixed seed batches on the basis of colour to exclude those with the fertile maintainer. NIAB and Elsoms have identified, sequenced and cloned a wheat blue-aleurone gene for use in tracking the early pollen-development trait.

Figure 3. Male sterility in NIAB/Elsoms system. Pollen staining: pale colour indicates empty/non-viable pollen (a, male-sterile line AK 19-28), dark colouration indicates viable pollen (b, fertile control line cv. 'Fielder'). Single florets from the same two lines (c and d, respectively) show that flower morphology is otherwise unaffected



By first inserting our maintainer genes then producing male-steriles these three genes can together form a genic hybrid system which allows the production of fully-restored F1 hybrid seed, while still maintaining the potential for normal genetic gains through a conventional breeding programme. This system can readily use conventional pollinator lines for test hybrids and commercial seed production.

Genome editing allows us to target the insertion of functional alleles of these genes at specific points in the wheat genome, and then perform precise related knockouts, to create maintainer lines and male-sterile seed production components in a cost-efficient manner. There is no non-wheat DNA in our hybrid system, and wheat genes are only moved or mutated as can occur naturally. By using only native wheat genes, this system falls within the framework of technologies permitted by the new Precision Breeding Act in England. Increasingly other parts of the world are also 'freeing up' their legislation to enable these new genomic technologies.

We are very encouraged by the keen interest shown in implementing our system starting with wheat breeders in the USA, where there is a large wheat market and a well-developed assessment and acceptance of new genomic techniques – and long-standing familiarity of the benefits of hybrid maize.

NIAB

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- Approximately 6,500 m^2 of controlled environment glasshouses and specialist plant growing facilities combined across the sites including spore-proof growth rooms, growth chambers, containment and vertical farm unit and vernalisation areas
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Glasshouse capabilities

- Biostimulant trials
- Nutrition and water management
- Seed bulking
- Fertiliser and crop protection products
- Herbicide efficacy trials
- Growing media trials.

NIAB glasshouse services include:

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- Impartial assessment
- Phenotyping
- Data handling and analysis
- Genetic resource maintenance
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- Additional analytical services available via NIAB LabTest

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Pathology into practice – IPM for wheat diseases

Dr Aoife O'Driscoll is a senior plant pathologist in the Farming Systems and Agronomy team at NIAB. She works across multiple teams and disciplines to turn NIAB's crop protection research, agronomy and knowledge transfer activities into best practice on-farm.

In the previous issue of NIAB *Landmark* (Autumn 2023, Issue 53) we looked at how appropriate variety selection and adjusting drill dates can lay a solid foundation in reducing the requirement for fungicide chemistry to prevent and eradicate disease. However, with the 2023 autumn drilling campaign proving challenging for many, knowing the risk of disease ingress and progression in the crop will be essential to stay one step ahead and maintain disease control this spring. Cereal fungicide strategies must consider a myriad of factors, and this is where NIAB comes into its own, through the availability of pathogen diagnostic and disease surveillance tools, independent efficacy trials data and weekly agronomic updates providing guidance as the season progresses. These will be summarised in this article – part 2 of 'Pathology into practice – IPM for wheat diseases'.

Know your enemy; improved diagnostics

While cereal pathogens continue to evolve, our understanding of their dynamics changes with every season, largely through the longest running pathology project at NIAB; the UK Cereal Pathogen Virulence Survey (UKCPVS). Funded through AHDB and APHA, the UKCPVS team at NIAB, led by Dr Charlotte Nellist, monitors annual changes in pathogen virulence for rust pathogens of both wheat and barley and has been in operation for nearly 60 years. In that time, major changes have been detected, such as the incursion of the Warrior population in 2011, and new technologies have enabled NIAB to dissect these changes in ever greater detail.

The importance of coordinated pathogen monitoring at both local and national levels cannot be underestimated, nor should the influence of globalisation and pathogen movement across countries and continents. NIAB was part of the Horizon 2020 funded Rustwatch project that brought together over 20 partners from academic research, industry and advisory services across Europe. This collaboration allowed a better understanding of the biology and epidemiology of cereal rusts (Figure 1), and develop early warning systems at a range of geographic levels to mitigate the risks and impacts of future changes in rust pathogen populations (Figure 2).

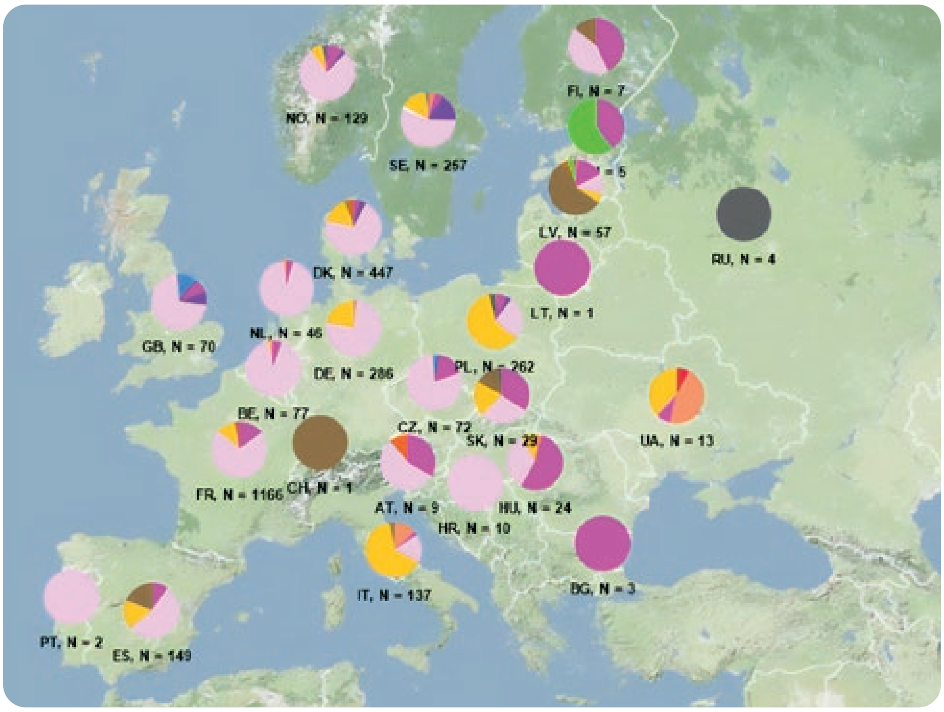
Catch it early; predictive disease management

In our efforts to keep disease out of crops, rather than trying to cure it once established, one piece of information often remains missing – how far has the disease progressed in the crop without showing symptoms, and how much disease may appear in the future?

These parts of the puzzle are problematic for diseases with long latent periods like Septoria, while simultaneously influencing appropriate product choice, timing and rate to protect yield building leaves from disease. In 2017, NIAB began working with Bayer Crop Science to provide a PCR (polymerase chain reaction) based leaf testing service for growers and agronomists. These tests check for and quantify latent Septoria and yellow rust in winter wheat crops by detecting genetic material from the pathogen or an abnormal cell sample. Results from

Figure 1. Symptoms of yellow rust, brown rust and black stem rust on wheat

Figure 2. Distribution of yellow rust genetic groups from 2015 to 2023



NIAB laboratory testing fed quickly into the Bayer CropCheck traffic light scoring system to provide growers and agronomists with a near-real time steer on the phase of infection in the leaf layer sampled. Coupled with variety and agronomic factors, CropCheck added an additional piece of information to evaluate disease risk and steer an appropriate response in the field.

Fungicide planning

Knowledge of the potential power of an active ingredient together with its optimal use helps growers and agronomists gauge the potential return on their fungicide programme and balances the need to control disease with the need to protect chemistry from fungicide resistance. NIAB agronomists continue to develop and refine a risk-based approach to cereal disease management, aiming to identify the most cost-effective strategies across seasons and give the NIAB Agronomy Membership a range of options depending on their attitude to risk (Figure 3). These strategies are guided by data from our membership-funded efficacy trials that are located to cover the key disease threats in each region, testing best placement and performance of fungicide products at a range of rates and timing. Annual trial results are summarised in the Members' Trial Results and Variety Interactions Handbook which, along with our four Agronomy Strategy documents, remain amongst our most used publications.

Cross industry collaboration is paramount in providing evidence-based consensus on fungicide performance to the wider industry, and no more so is this evident than the AHDB-funded Fungicide Performance project, in which NIAB is a partner together with ADAS, SRUC, Teagasc and Harper Adams University. It provides growers and their agronomists with robust, independent trials data on the protectant and curative activity of new fungicide active ingredients compared to existing products against key diseases in wheat, barley and oilseed rape. The project also acts as a long-term information resource, with efficacy data available on winter wheat disease since 1994 and winter barley disease since 2002.

Maximising efficacy by minimising resistance

For fungicide programmes to provide adequate disease control and to minimise the risk of resistance development, up-to-date information on the resistance status of key pathogens to the main fungicide modes of action used to control them is essential. In the UK, shifts in sensitivity to azole and SDHI chemistry are independently monitored by NIAB through another long-running AHDB-funded project that links to the AHDB Fungicide Performance winter wheat trials. Under the stewardship of NIAB's Dr Nichola Hawkins, the project establishes baseline sensitivities for new actives entering the market, and monitors shifts in sensitivity in UK Septoria populations to key fungicides belonging to different mode of actions.

Figure 3. Discussing wheat disease control in practice at a NIAB open day

Results of the project are shared annually with both levy payers and the wider industry, while guiding the views and recommendations of the UK Fungicide Resistance Action Group (FRAG-UK). This group consists of representatives from crop protection companies, the wider agrochemical industry, independent organisations (including NIAB), public-sector research institutes, and the HSE Chemicals Regulation Division (CRD). FRAG-UK aims to gather and interpret information on fungicide resistance and management to arrive at a unified consensus view for the UK, translating this into practical guidance on the status and management of fungicide resistance.

Smarter surveillance of fungicide resistance

To manage fungicide resistance proactively, we need to be able to predict how it will evolve. Moving from a reactive to a predictive approach to resistance against new crop protection measures would enable resistance risk assessments and resistance management guidelines to be put in place as soon as the measure is introduced. Funded by a prestigious BBSRC Discovery Fellowship, Dr Hawkins is investigating whether the lessons from decades of resistance evolution against chemical fungicides can be applied to new methods of crop protection. NIAB is taking an experimental evolution approach, combined with high throughput sequencing, to quantify the differing levels of evolutionary repeatability seen for resistance against different crop protection products in plant pathogens. Dr Hawkins will also investigate how the principles of resistance evolution apply beyond chemical pesticides, for example to biological control and to RNAi (RNA interference; suppression of gene expression).

Predicting future risk is important, but so too is improving our capabilities in the present. Targeted approaches to fungicide usage based on near-real time knowledge of resistance in local pathogen populations will minimise over-use of ineffective chemistries, helping to maximise the lifespan of available chemistry. However, development of a UK-based independent service to provide this knowledge has been limited due to the prohibitive costs of testing and the high level of expertise required to deliver the testing. To address this gap, NIAB, led by Dr Tom Wood, has developed a high-throughput Oxford Nanopore-based amplicon sequencing approach for screening Septoria populations for fungicide resistance (Figure 4). Through additional grant support from the BBSRC Follow-On Fund, this work has progressed to the commercialisation phase, providing a high throughput, low-cost fungicide resistance monitoring service platform for chemical companies, agronomists and growers.

The spectrum of pathogens on cereal crops continues to change over time and our response to this change will continue as we work with our funders and partners to produce high quality, independent and reliable information to the wider agricultural industry. While varietal resistance and fungicide efficacy testing has formed the core of pathology activities at NIAB, our research activities on pathogen populations have moved on apace. New diagnostic methods, sequencing technologies and bioinformatics pipelines will add value to testing systems rather than replacing them. As sustainability concerns lead the agricultural industry to look increasingly at non-chemical forms of crop protection, these new control measures must also be used sustainably to maximise their efficacy and prolong their lifespan. High throughput, cost-efficient services to monitor and inform on resistance developments will prove even more essential in disease control product development pipelines, as will our applied pathology, agronomy and knowledge transfer expertise to support best practice and use of crop protection strategies on-farm.

Figure 4. Nanopore sequencing can rapidly detect any mutations in a fungicide target site gene

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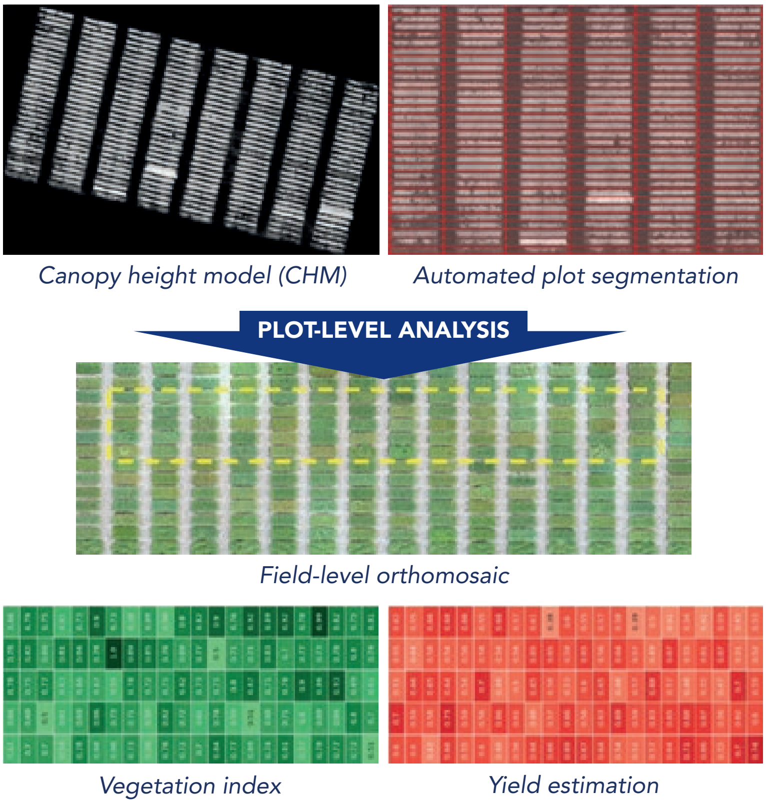

NIAB's offering:

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- Ear counts
- Plant performance and health
- Vegetation Indices
- Dynamic Crop Growth (Minimum five flights)
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Using artificial intelligence for variety identification

Artificial Intelligence; is it a force for good or a force for evil? A question that has regularly been asked in the media in recent times. This mostly focuses on the grand scale or doom mongering but what are the impacts for agriculture and what meaningful contributions in the Agri-Food sector it is having now? This articles outlines some of the ways the AI/Data Science team at NIAB is utilising AI to identify varieties based on photos as part of the One CGIAR Seed Equal Initiative.

Dr Robert Jackson and Felipe Pinheiro are part of NIAB's Data Sciences Department headed by Professor Ji Zhou. Focused on artificial intelligence driven, multi-scale indoor and in-field plant phenotyping, they work on projects across the UK and globally focusing on numerous crops from cereals, to soft fruit and vegetables.

Since our establishment in early 2020 the Data Sciences Department at NIAB has been using AI and machine learning techniques to advance multi-scale phenotyping and AI-powered trait analysis capabilities across NIAB and with academic and industrial collaborators. For example, NIAB uses the drone-based aerial phenotyping platform, AirMeasurer, and IoT-based sensing (e.g. CropSight and CropQuant™) for monitoring agricultural and horticultural crops during the season. Equipment such as the Videometer and SeedGerm platforms are used to monitor seed quality, germination, and vigour testing.

After a recent BBSRC award NIAB jointly established a UK leading high-performance computing (HPC) and GPU clusters infrastructure with the James Hutton Institute, and other partners, for results dissemination, cloud-based informatics and AI predictive modelling. With this background, One CGIAR asked us a simple question, can you build an AI method to identify specific food crop varieties from just a few pictures of the crop?

For context, One CGIAR (www.cgiar.org) is a global research partnership for a food secure future, dedicated to transforming food, land and water systems in a climate crisis through a $1 billion annual research portfolio. The partnership unites 15 international organisations and has 10,000 staff working across 89 different countries, producing science that has brought benefits to hundreds of millions of people around the world. One CGIAR supports innovative solutions to improve food security, increase biodiversity, stimulate economic growth and strengthen resilience of farming systems. A key part of this is Seed Equal (Delivering Genetic Gains in Farmers' Fields), which aims to support the equitable delivery of seed adapted to the various agronomic, climate and

Figure 1. AI based trait identification from wheat images – in this case, counting of wheat ears

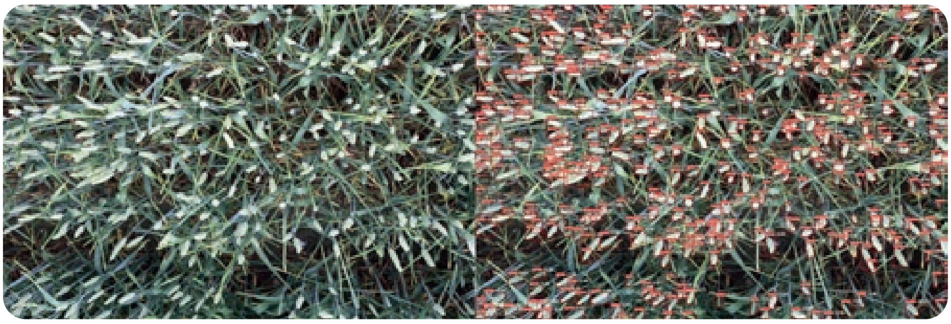
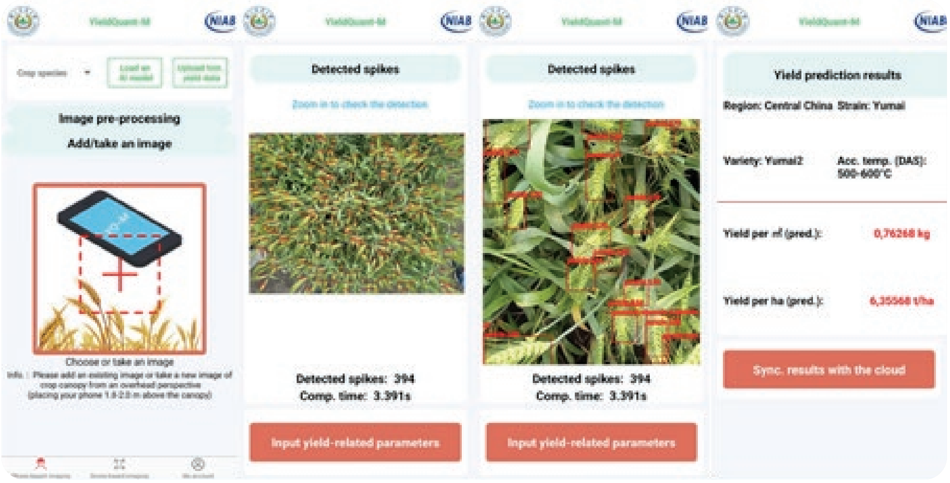


Figure 2. Examples of ear count and yield prediction using the NIAB/Nanjing University YieldQuant-M app



market challenges that farmers face. A fundamental of Seed Equal's activities is to carry out AI-powered varietal identification.

Dr Ian Barker, a senior director for strategy delivery and scaling in the One CGIAR Genetic Innovation Science Area and is also based at NIAB in Cambridge, made the initial connection with Professor Zhou. He is convinced by the power of AI for varietal identification: "I have observed potato experts at NIAB being trained in correctly identifying 200 different potato varieties. If humans can do this, AI can also do it this with our domain knowledge". This will also facilitate the accurate measurement of adoption rates of CGIAR varietal technologies and the prediction of yield to better measure genetic gain in farmer fields.

And this is where the AI/Data Sciences team at NIAB comes in. Through the awarded CGIAR initiative, we will contribute to "Combining cloud- and smartphone-based AI solutions for varietal identification of wheat and potato", a project aims to advance the vision-based AI modelling tailored for varietal identification using cutting-edge AI algorithms such as Transformer and Visual Attention. Currently, NIAB has pioneered AI-models to assess key yield components in wheat and are developing AI-based image recognition algorithms and open-source software (Figure 1). With One CGIAR the ambition is to integrate this into VarScout (https://varscout.org), a digital ecosystem designed to record, store, and visualise crop varietal data on a local, national and international scale (Figure 2).

Dr Marcel Gatto, a senior scientist and agricultural economist at the International Potato Center and co-lead of this project highlighted that smallholder farmers in developing countries often do not know the identity of the varieties they are growing. Methods for accurate varietal identification exist, such as DNA fingerprinting, but are very costly and results are only available after months. Powering VarScout with AI tools is a much-needed innovation to provide cost-effective and real-time varietal adoption and yield data without compromising on data quality.

This work has three main components: 1) the development of AI-based models for cloud-based variety identification in wheat; 2) the integration of phone-based yield prediction and variety identification models into an Android application (APP) (Figure 3); and 3) the verification and improvement of the APP using One CGIAR's resources for other food crops, such as potato, beans, etc.

To do this, first we needed to collect a set of images with which we could build a training set. And so Felipe Pinheiro, from the Data Science group, packed his bags and flew off to Ethiopia. Ethiopia presents an interesting trial location for this work. Hosts of crop inspectors travel far and wide across the country to collect samples for DNA identification

Figure 3. The VarScout app showing variety location in a region

Figure 4. NIAB's Felipe Pinheiro in Ethiopia training crop inspectors in plot imaging

of different wheat varieties, and if they are collecting samples, they could also collect images? This would provide us with a dataset of variety images tied to known varieties.

Before image collection across the country could happen, Felipe spent a week training numerous groups of inspectors in the specific protocol for photographing wheat with camera phones provided by the One CGIAR team on the ground (Figure 4). Whilst this sounds simple it is a key step. The success or failure of an AI prediction model regularly rests on the quality and number of images that will be used in training the AI models. Another important success factor is to take the pictures from agronomic varietal trials where the 20 most dominant wheat varieties were planted as, on smallholder farms, wheat fields can be a mix of different varieties. Therefore, Felipe had to train 100+ inspectors in a new method of image collection, ensuring consistent and high-resolution images with right organ parts acquired.

Now completed, this dataset along with a similar one from the UK are being used to build a baseline AI model for key and variety identification. This is where the cutting-edge AI aspect comes into the project with attention mechanisms (a process assigning different weights to different parts of the image based on the relevance to the task at hand) to identify defining organ parts, by which specific varieties can be identified from the high-level (colour and shape) and low-level (texture and pixel connections) features in the photographs. Once completed, the prototype will be tested in 2024 verses farmers' responses and DNA fingerprinted data collected for the same varieties. Finally, we will explore incorporating the app into the current VarScout app aiding farmers, agronomists, extension workers or anyone to record the location of where a particular crop variety is growing based solely on imagery.

So, how is AI helping farmers now? Well, we are already using it in field mapping and grain assessment in breeding, and the next step for the AI/Data Science team and One CGIAR is phone-based variety identification and yield predictions allowing us to accurately monitor yield and measure genetic gains in farmers' fields.

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NIAB's genetics research supporting advanced fruit breeding programmes

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.

Professor Dan Sargent is Head of the Plant Genetics Department at NIAB, responsible for the delivery of cereals and broad-acre crop genetic research; crop diversity focusing on genetic resources including germplasm development and characterisation and population genetics; and fruit genetics particularly flowering time and quality traits. Professor Sargent's own research interests lie in the molecular genetics and genomics of Rosaceous species and their wild relatives.

Fruit breeding was established at NIAB's East Malling site in Kent in the 1920s, the first fruit variety *Wellington XXX* blackcurrant being released in 1927. Raspberry breeding also began in the 1920s, with virus-tolerant varieties such as *Malling Jewel*, *Malling Promise* and *Malling Exploit* all being released over the ensuing 20 years and all being adopted enthusiastically by the industry. *Malling Admiral*, *Malling Delight* and *Malling Leo* were subsequently released offering improved pest and disease resistance. More recently, in the late 1980s, *Autumn Bliss* became the first primocane variety, (a cane that fruits in its first year of growth), to be bred for UK conditions and the summer fruiting *Octavia* followed in the 1990s to bridge the gap between the summer and autumn fruiting varieties.

It took until the 1980s for East Malling to start strawberry breeding, when the programme that had been run at Long Ashton Research Station near Bristol was transferred to Kent and funded by Defra. In recent years it has been NIAB's most prolific programme; since 1988, a total of 48 varieties have been released to the industry, many of which are now considered to be industry standards. Latterly the East Malling Strawberry Breeding Club was funded and supported for more than 15 years by a consortium of both industry and public funders. The success of this programme has been further highlighted through its recent acquisition by Bayer's crop science division.

In tree fruit, the Malling (M) and Melling Merton (MM) apple rootstocks have become synonymous with East Malling, as they are used in virtually every part of the world where apples are grown commercially today. One of the earliest research programmes to be set up, following the establishment of the then East Malling Research Station in 1913, was the study of factors affecting growth and yield in apples and pears, and in particular the influence of rootstocks on tree growth. This work led to the collecting and typing of apple rootstocks, and the propagation and release of newly-bred M and MM selections with defined effects on precocity and tree vigour. The MM series was developed jointly with the John Innes Institute, then located in its original home of Merton Park in Surrey, but now known as the John Innes Centre in Norwich. Rootstock breeding for other tree fruit crops has yielded the widely used quince rootstocks QA and QC for pear, *St. Julian A* and *Pixy* for plum, and *Colt* for cherry.

Apple scion breeding at East Malling has also led to a series of varieties that have been adopted by the industry, and from the 1950s onwards has included *Tydeman's Early Worcester* and *Tydeman's Late Orange*, *Malling Kent*, *Malling Greensleeves*, *Fiesta*, *Meridian* and most recently the pink-fleshed variety *Sunburst*®. The new pear variety *Concorde* was also bred and released and the new early plum variety *Malling*™ *Elizabeth* was released only last year. The cherry varieties *Colney* and *Penny* (Merton series) were also bred from collaboration between East Malling and the John Innes Institute.

The vast majority of the varieties bred at East Malling in the past have followed the conventional breeding approach of cross pollinating flowers from two parents, collecting the resulting seeds, and growing these on to allow our plant breeders to assess the thousands of resulting progeny. This is a very time-consuming process, ranging from eight to ten years between crossing to variety release in strawberry to more than 25 years for the same process with apple. The process is lengthy, but it is also imprecise, with 'linkage drag' meaning that unfavourable traits are often inherited along with favourable ones, and successive generations of crossing is required to breed out detrimental characteristics.

During the 1980s and 1990s, UK government funding sources allowed the then East Malling Research to begin research in the area of genetic modification (GM), with the aim of producing new plant types, either to speed up what could be achieved by conventional breeding or to introduce genetic material from different species. This approach offered the opportunity to insert genes conferring improved characteristics in fruit varieties, including improved disease resistance, but the ongoing public concern over GM technology resulted in government terminating the funding of such projects.

Genome sequencing

Since then, NIAB has been able to continue a programme of genetic improvement in its breeding programmes through the availability of molecular analytical technologies that make possible the sequencing of the genome of an organism. Scientists have been able to construct complete genetic maps for perennial rosaceous fruit crops. An early breakthrough was the sequencing, by NIAB in collaboration with an international consortium, of the entire genome of *Fragaria vesca*, the wild woodland strawberry that is a progenitor of the cultivated strawberry. The advantage of *F. vesca* is that it has a simpler genome as it is a diploid, whereas the cultivated strawberry is octoploid. Nonetheless, *F. vesca* is a valuable model for high-resolution genomics analysis of commercial grown strawberry, and indeed other rosaceous perennials.

Particular plant characteristics can be controlled either by major genes, or by quantitative trait loci (QTL) which is a region of DNA associated with a specific phenotype or trait that varies within a population. The molecular genetics of a particular trait can be explored by crossing a variety that possesses the trait, with one that does not; the segregating progeny can then be characterised both genetically and phenotypically (the physical properties and appearance of the plant) and associations made between a trait and a particular sequence or region of DNA code. This allows NIAB to characterise genetic markers associated or 'linked' to the genes controlling the trait in question and to use the marker to predict the phenotype, without having to observe the trait in the field, thereby facilitating what is known as marker assisted breeding.

Marker assisted breeding has significantly enhanced our ability to breed varieties with improved quality traits, but also reduced the time taken to identify the elite progeny arising from a conventional cross made by the breeder. Once molecular markers have been identified for traits such as pest or disease resistance or fruit quality traits, we can quickly discard any progeny that do not possess these markers, reducing the time that was previously taken to grow the progeny on and assess pest/disease resistance or fruit quality over a period of years.

Marker assisted breeding is now being used in all NIAB fruit breeding programmes at East Malling. Our strawberry breeding team have been using molecular markers that confer resistance to *Phytophthora cactorum* and work by our genetics group has identified genes responsible for several plant and fruit traits that the breeders can employ in the various NIAB breeding programmes.

BBSRC-funded research at NIAB has helped us to identify marker genes that confer resistance to apple canker and this knowledge is now being utilised by our apple breeders. In rootstock breeding, we are using markers linked to the two main fireblight (*Erwinia amylovora*) genes, along with dwarfing-related genes. In cherry, resistance to bacterial canker can also be identified much earlier than before using this technology. The results of our genetic research, now being incorporated into all of NIAB's fruit breeding at East Malling, is helping to develop superior varieties in all of our programmes.

Strawberry breeding has been particularly prolific in recent years, releasing the mainseason varieties *Malling™ Centenary*, *Malling™ Vitality* and *Malling™ Allure*, and the everbearer varieties *Malling™ Champion*, *Malling™ Supreme* and *Malling™ Ace*. All of these have been very widely adopted by the industry, with around 390 million plants sold since *Malling™ Centenary*'s release in 2013. Two new primocane raspberries, *Malling™ Bella* and *Malling™ Charm* were released in 2017. The apple rootstock M200 also shows huge promise, offering vigour between M9 and M26, similar precocity to M9, and is on average, 35% more productive.

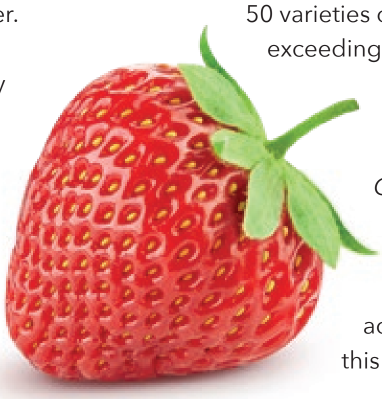
With the production margins for fruit crops continuing to decline, the survival of our UK fruit industry is reliant on improved yields of higher quality fruit. Breeding programmes hold the key to such improvements and further adoption of genetic technology will continue to aid us in our quest to help and support the UK fruit industry through these tough times.

NIAB's strawberry breeding programme moves to Bayer

NIAB's strawberry breeding programme, including the strawberry varieties within the Malling™ Fruits portfolio, has been acquired by Bayer.

The move allows NIAB to concentrate on its soft fruit research, similar to its already established programmes in arable crops, as the organisation moves to prioritising the provision of translational research to benefit growers, consumers and the environment. It will also open up new opportunities to work with leading soft fruit breeders and propagators across the industry, including Bayer.

Under the terms of the transfer, finalised in January 2024, the strawberry programme will continue to operate from NIAB's East Malling site in Kent. NIAB retains the raspberry and cherry variety breeding programmes.



NIAB is extremely proud of the strawberry breeding programme that first began at East Malling in 1983 and more recently, from 2008 to 2023, was funded via the East Malling Strawberry Breeding Club (EMSBC) with investment and support from both public and private companies, to which we thank all those involved.

In that time NIAB launched nearly 50 varieties of soft fruit with sales exceeding 400 million plants, including the popular and well-known strawberry *Malling*™ *Centenary* and raspberries *Malling*™ *Bella* and *Malling*™ *Charm*. Bayer's acquisition will ensure this success, and legacy, is

protected and strengthened, opening up new opportunities and markets for this leading programme. NIAB looks forward to continuing our links with Bayer, ensuring the benefits of high-quality crop research and innovation are transferred effectively into practical agriculture.

Will Smith

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Optimising plant spacing for narrow row crops

In a season when crop growth is limited more by the availability of sunlight than the supply of water, the formation of yield depends on maximising the capture of solar radiation. Therefore, it follows that seeds should be spaced to create an optimum spatial arrangement of plants that produces a canopy of foliage that maximises light interception. However, other management factors have influenced the choice of row widths and plant densities. For instance, drills capable of operating in conjunction with non-inversion tillage are often equipped with wider spaced coulters to better enable the flow of trash through the drill. What effect are these wider spaced rows, with plants more closely packed into the row space, having on the way the resulting crop canopy intercepts light and produces grain?

This question was being given a lot of thought by David Passmore, an Oxfordshire farmer, who felt that a shift to wider rows might have negative impacts on his wheat yields. Having seen ADAS analysis of Yield Enhancement Network (YEN) data, which indicated that narrow row widths were associated with higher grain yields, he wanted to explore this further by conducting some trials of his own. "Crops such as sugar beet and maize are established with precision drills in the UK to help achieve optimum plant densities and spacings, and I pondered how this approach might work for a crop such as winter wheat."

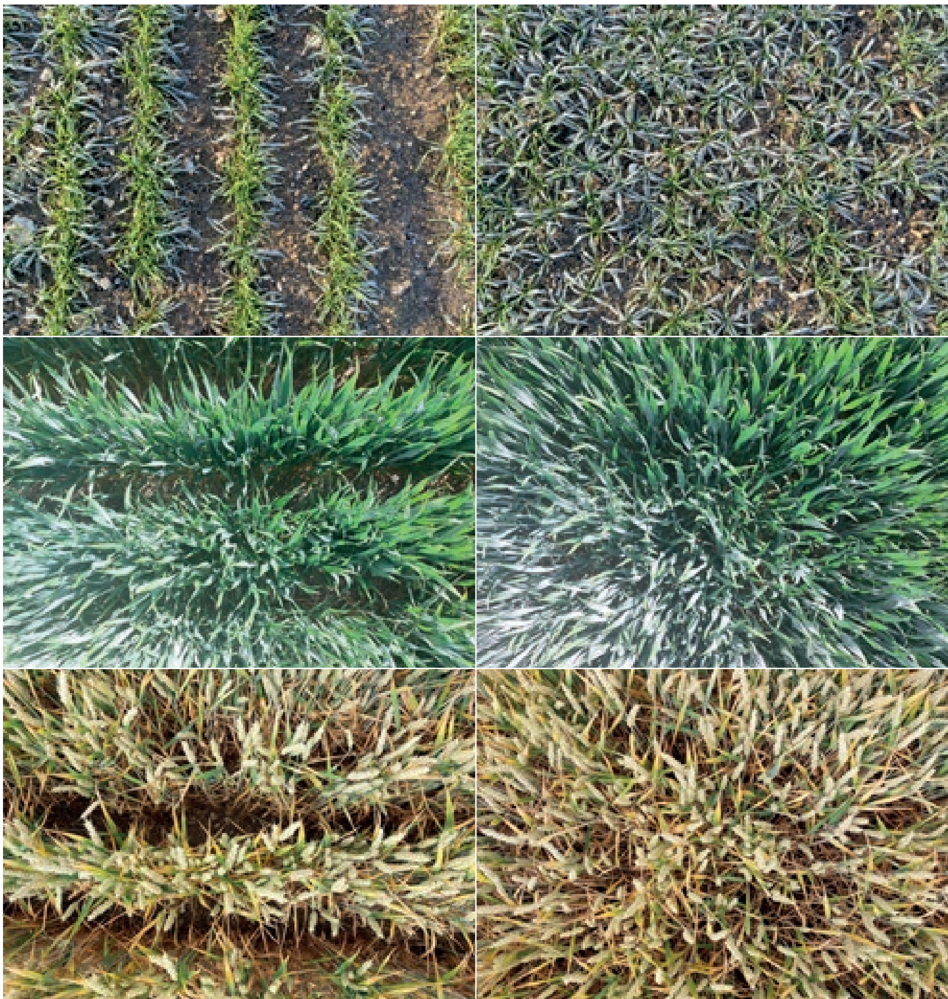
In 2022, David was involved in the FarmInn initiative, funded by Rothamsted Research and AHDB, which compared a crop using conventionally-drilled rows at 12.5 cm spacing with cross-drilling (one pass of the drill with 12.5 cm rows at half seed rate, followed by another pass perpendicular to the first). The cross-drilling resulted in the same plant population density as the conventional method, but the cross-drilled crops had plants between the rows where conventionally there would be none. In this unreplicated farm trial, 0.7 t/ha uplift in yield was associated with the double-pass method. This was an initial positive result, but David thought there was a further step to this journey. Was there room for additional improvements in the spatial arrangement of plants?

David, in collaboration with NIAB and ADAS, won a grant from Innovate UK's Farming Innovation Programme to test a range of spatial planting arrangements in 2023. A replicated, randomised trial was

Dr Eric Ober works in the Farming Systems team as a Research Agronomist specialising in crop physiology. He has worked on a range of crops including maize, sugar beet, oats and wheat, and research has focussed on the physiological determinants of yield, field phenotyping for breeding crop improvements, drought tolerance, and root system growth and development.

Will Smith is a weeds specialist and was part of the NIAB Farming Systems team until January 2024.

Figure 1. Images of the plots with 25 cm row spacing (left column) and the hand-planted hexagonal spacing (right column) taken on 17 January (top row), compared with 25 May (middle row) and 10 July (bottom row)



set up on David's farm, with treatments including a repeat of the farm standard 12.5 cm rows, wide rows (25 cm), 12.5 cm rows cross-drilled, and a precision-planted hexagonal arrangement that maintained uniform seed spacing both within and between the row. The latter was sown by hand, as machinery for this kind of precision planting was not available. The seeding density was the same for the drilled treatments (360 seeds/m²), but the hand-sown treatment was 200 seeds/m².

A range of assessments were made to help elucidate the effect of the different treatments on canopy development, light interception, incidence of disease, lodging, etc. The development of the crop canopy at multiple times across the season was measured using remote sensing methods via hand-held and UAV-mounted sensors that detected green vegetation recorded as NDVI (Normalised Difference Vegetative Index). Interestingly, despite the greater soil coverage by foliage in the precision-planted crop early in the season (Figure 1), there were no significant differences in canopy cover between any of the treatments by the time of heading in May (Figure 2). Although the leaf area index (LAI) and light interception in May were slightly greater in the crop precision-planted in a hexagonal pattern compared with the other plant spacings, these differences were likely too small to have had much of an effect. This illustrates the capacity of wheat to fill gaps in the stand by producing tillers. Thus, not only the physical arrangement of plants due to seed placement is important for light and soil resource capture, but also the 'plasticity' of the crop: the capacity of a variety to produce tillers – and perhaps also alteration of root system architecture – in response to the proximity of neighbouring plants and the local environmental conditions of available space, light, water and nutrients.

Surprisingly, despite the near complete closure of the canopy in all treatments by the end of May, the crop planted on a hexagon arrangement showed a significant yield advantage over the other drilling patterns: a 0.8 t/ha boost over wide rows, and a 1.1 t/ha uplift compared with 12.5 cm-spaced rows (Figure 3). There were no differences between the other treatments, and unlike the preliminary results in 2022, there was no positive effect on yield using the cross-drilling method. Despite starting out with a lower seeding density, the crop that was precision-planted in a hexagonal pattern finished with similar numbers of ears/m² as the other treatments, which also did not differ, and therefore ear density could not explain the yield effect. The slightly greater number of grains per ear in the precision-planted plots may have contributed to the higher yield.

The spatial arrangement of plants within a crop has been suggested to influence the management of disease and weeds. Wider rows may increase air flow and help to reduce the spread of disease through the crop, but also allow greater rain splash from unprotected soil between the rows. In this trial, a greater disease burden appeared in the lower foliage of the wider rows (Figure 4), but Septoria scores on flag leaves did not show any differences between the treatments. All plots had been treated with a full fungicide programme so the overall severity of disease was low.

It is well known that crops planted at higher densities and spatial uniformity (therefore not just greater numbers of seeds in the row) can improve competition with weeds. Wider rows

Figure 2. The NDVI, which reflects green canopy coverage, leaf area index, light interception, and % green canopy cover estimated from plot images measured on various dates in 2023. F probabilities <0.05 indicate a significant effect of planting arrangements. The least significant difference (LSD) for the treatment effect is shown

Spatial planting arrangement	NDVI 7 June	Leaf area index 25 May	Light interception 25 May (% incoming)	Green canopy coverage 25 May (%)	Green canopy coverage 10 July (%)
25 cm rows	0.784	6.3	97.1	81.2	24.4
12.5 cm rows	0.796	6.0	97.0	82.3	24.8
Cross-drilled (12.5 cm)	0.793	5.7	96.6	87	18.1
Hexagonal-planted	0.798	6.7	97.9	83	22.3
F pr.	0.646	0.005	0.026	0.361	0.395
LSD	0.023	0.052	0.82	7.3	9.3

Figure 3. Grain yield and the component variables that contribute to yield, as measured by plot combine and the manual harvest of the YEN samples

Spatial planting arrangement	Yield (t/ha)	Ears/m²	Grains /ear	TGW (g)	Tillers/m² 4 May
25 cm rows	13.62	613	46.6	47.8	443
12.5 cm rows	13.29	585	47.3	48.8	620
Cross-drilled	13.47	585	49.3	46.8	587
Hexagonal-planted	14.41	558	60.4	44.0	466
F pr.	0.044	0.610	0.073	0.288	<0.001
LSD	0.78	89.8	11.4	5.455	50.4

are less competitive in the early part of the season, and slower canopy closure reduces shading, which can encourage the germination and growth of weeds such as spring wild oats, meadow/rye bromes and a range of broad-leaved weeds. The site was not weedy in nature, so no conclusions can be drawn from this trial about the effect of spatial planting patterns on the level of weed control.

The physical arrangement and density of plants within a crop can have effects on stem length and strength. "There were visible differences in the crop as we approached harvest – the taller crop in the wide rows felt less secure, compared to the other treatments which had a firmer and stiffer feeling to them," explained David. "Even though all plots had a robust PGR programme, moderate lodging showed a risk of wider rows". Although height differences did not reach statistical significance, the trends suggest that the more uniform spatial arrangement of plants in the hexagonal pattern resulted in shorter plants, compared with the wide rows (Figure 5).

Grain analysis demonstrated that the wide row treatment was associated with higher concentrations of N (Figure 5) and major nutrients (P, K and S) compared with the precision-planted plots. It may be possible that lower concentrations were due to the commonly observed 'dilution effect', whereby a fixed amount of N is taken up by a plant, but distributed to a greater number of grains. In addition, the wide row plants may have had less below-ground competition with neighbouring plants for soil nutrients, allowing greater accumulation of nutrients in the plant.

The evidence for yield benefits from precision placement of seeds to establish a uniformly spaced population of plants is encouraging, although this trial was only one site in one year. Clearly, more work is required to understand the underlying mechanisms and to assess the repeatability of the results. In future work, it would be interesting to see how the spatial patterns of plant placement affect disease and weed control under conditions of greater disease and weed pressure than we experienced here. There may be important differences to investigate between varieties in their tillering potential and root development in how they respond to equidistant planting versus wide rows.

From a practical standpoint, more R&D would be required to develop a one-pass solution that can precision drill cereal crops to the configurations tested in this trial. Precision drills are commonly used for sugar beet and maize, and some manufacturers are now selling these for cereals. However, how to get the coulters close enough together for narrow rows and still handle the trash remain challenges, and this approach is still limited to simple row configurations. Equidistant seed spacing in all directions can be approximated by broadcasting, but control of seed depth and spacing is far from precise. In future, a robotic seed planter that can be programmed for any spatial configuration may be a feasible solution.

The intriguing result from this trial, which showed a clear yield benefit of precision placement of seed on in a hexagonal spatial arrangement that spaced seeds evenly in all directions, indicates that there is room for improvement in how crops are established. The move to wider spaced rows has advantages under certain conditions, but the findings here suggest that other configurations of plant placement may produce better returns in light-limited environments.

Figure 4. Photos of plots planted with wide rows (left column) and with seeds precision-placed in a hexagon pattern (right column). Disease levels within the canopy in the in late May (top row), and lodging prior to harvest (bottom row)

Figure 5. Plant height at maturity, grain N content and disease. Septoria was scored as % of flag leaf area affected by disease

Spatial planting arrangement	Plant height (cm)	Grain N (%)	Septoria (%) 30 May
25 cm rows	64.7	1.91	8.5
12.5 cm rows	63.2	1.80	9.3
Cross-drilled	63.3	1.77	7.0
Hexagonal-planted	61.5	1.76	5.8
F pr.	0.186	0.001	0.343
LSD	4.4	0.061	4.4

News from NIAB

NIAB Board, NIAB Trust and BCPC Advisory Board

There are new appointments and changes to the NIAB Board, the National Institute of Agricultural Botany Trust and BCPC Advisory Board for 2024.

Trish Malarkey has joined the NIAB Board. With a career spanning over 30 years in food and agritech innovation, Trish has held senior research and development roles in multinational businesses in the UK, Switzerland, The Netherlands and USA. These include Chief Innovation Officer at Royal DSM, Head of Global Research and Development at Syngenta and various non-executive director and scientific advisory roles in established global companies and start-ups. Trish's ability to bring together commercial business and R&D strategies, alongside her breadth of scientific technical expertise, and her knowledge of the global agribusiness industry, will provide NIAB with unique and valued insight in its future development.

Professor Alison Smith and Dr Nigel Kerby are retiring as Board members, and we thank them for their service and support of NIAB over the past eight years.

We also welcome Philip Wynn OBE and John Latham to the National Institute of Agricultural Botany Trust. Philip has been Chair of LEAF since 2017 and has a long career in agriculture, managing and advising businesses in nearly every sector of the industry. John is a Cambridgeshire farmer and former chair of Camgrain.

And finally, former NIAB Board Chair Tony Pexton is standing down from the BCPC Advisory Board. Tony first joined BCPC in 2010 as a BCPC Executive Member and BCPC Trustee. He is replaced by Hazel Doonan, who is Head of Crop Protection and Agronomy at The Agricultural Industries Confederation (AIC).

Mario becomes OFC Director

NIAB CEO Professor Mario Caccamo has joined the Oxford Farming Conference Board for a three-year term from January 2024. Commenting on his appointment, Professor Caccamo said, "I am delighted to join the OFC Council at a time of change for the farming industry, the most profound in generations. In the UK, we are leaders in delivering a more modern approach to farming which we should embrace, promote and celebrate. The OFC plays a unique role in supporting the farming industry in this transition, and I am looking forward to contributing to it."

Plant Genetics Department

NIAB's three crop genetics teams, based at Cambridge and East Malling in Kent, have recently come together under the same leadership as part of our 'One NIAB' strategy, ensuring stronger linkages across all NIAB's sites and agricultural and horticultural teams. The new Plant Genetics Department is led by Professor Daniel Sargent with Drs Stéphanie Swarbreck, Phil Howell, James Cockram and Chandra Yadav responsible for NIAB's work in: cereals and broad-acre crop genetics, focusing primarily on resource usage and crop nutrition; crop diversity, focusing on genetic resources including germplasm development and characterisation and population genetics; and in fruit genetics, focusing on flowering time and quality traits.

HRH Anne, The Princess Royal, visited NIAB Park Farm in late 2023, joining delegates at a BBSRC workshop on crop diversification and underutilised crops, before viewing examples of these crops on a tour of NIAB's glasshouses with CHCx3 project lead Dr Lydia Smith

NIAB

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- All work is strictly confidential
- Opportunity to share data and results with NIAB specialists and members
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NIAB field trials services include:

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- Accurate product application
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- Strict standard operating procedures to ensure data conformity across trial series.

Our service guarantees customer loyalty

Our customers believe that location is critical to product evaluation

Successful field trialling for over 100 years

Testimonial:

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"Despite product registration and a standard label, sometimes a new product may not work in all situations. We approached NIAB to carry out field trials because they could offer a range of locations and geographic environments. It meant we could provide correct advice to local growers on getting the best from our product."

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Cabbage stem flea beetle

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.

NIAB has continued work on the Defra-funded cabbage stem flea beetle (csfb) project, focusing over the past year on assessing if the previous year's reduction of adult flea beetles by using cultivations at harvest would be repeated. Over the past three years, emergence traps have been used to check if pupae in the soil after harvest were vulnerable to damage by cultivations.

In June 2023, emergence traps were deployed into fields, in Shropshire and Hertfordshire, to look at the emergence before harvest. Figure 1 shows a differential in the emergence from the soil in the two counties. The blue line from the Shropshire site clearly shows a significant amount of csfb adults emerged from the soil before harvest. At the Hertfordshire site, despite harvest being much later, very few had emerged from the soil before harvest.

The work continued looking at the effect of cultivation on several sites to see if the effects of cultivating after harvest could be repeated. A simple set of discs was used to cultivate at 50 mm and at 250 mm on the north Shropshire site. The emergence of the adults from the soil were then monitored. Cultivating at 250 mm gave a 69% reduction in emerging adults and cultivating at 50mm gave a 85% reduction compared to an uncultivated control (Figure 2).

On another Hertfordshire site the cultivations included a straw rake, a Claydon Terrastar at 50mm deep

Figure 1. Cabbage stem flea beetle adults emerging from the soil at two sites, prior to harvest

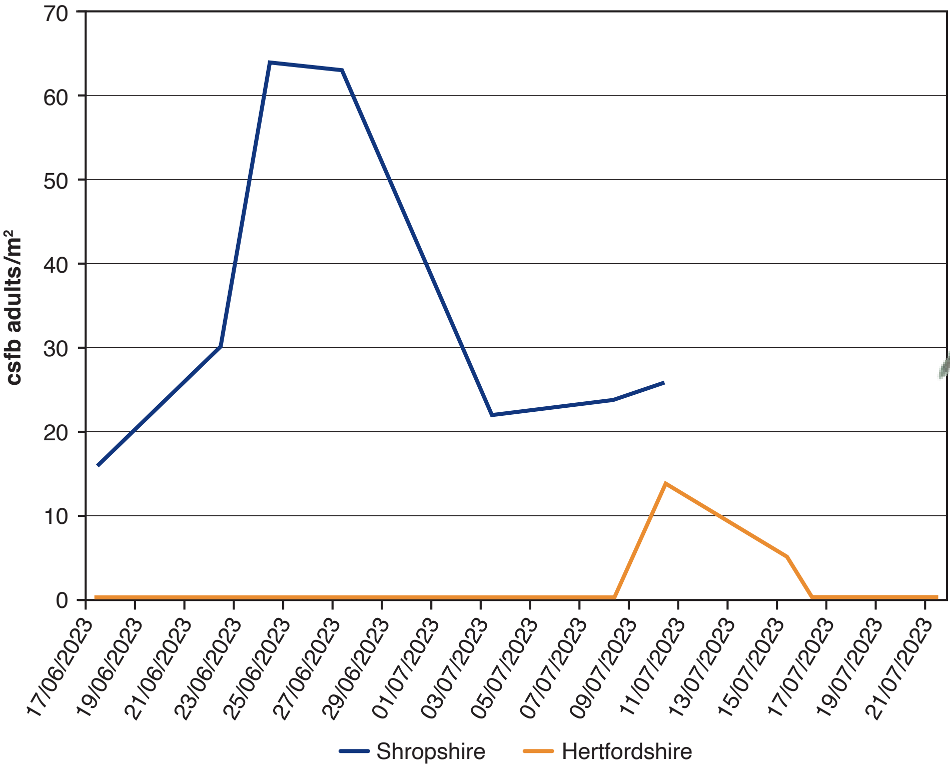
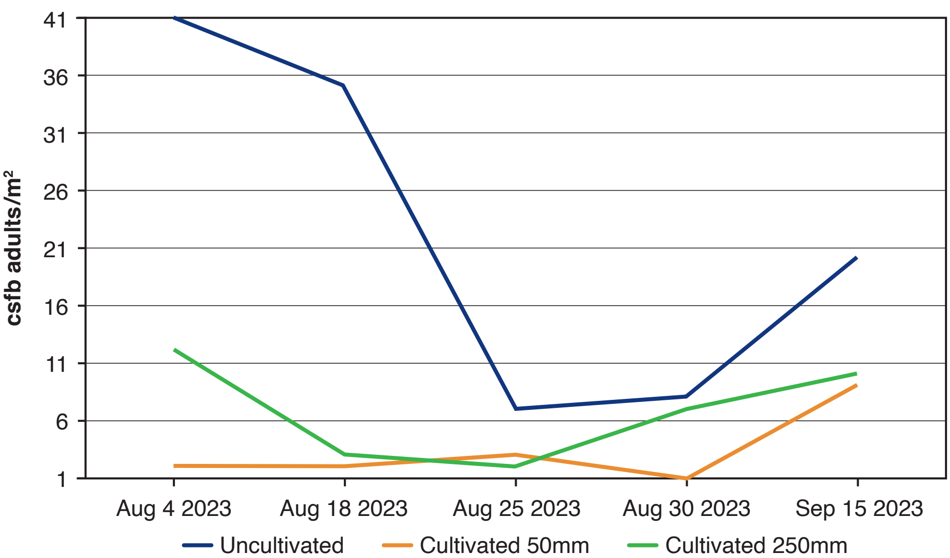


Figure 2. Cabbage stem flea beetle adults emerging from the soil after cultivations in north Shropshire



and a Sumo at 250 mm deep (Figure 3). The straw rake had limited success as the ground was hard at the time. The Terrastar was less effective than the disced plot, but still reduced the numbers by 50% and the Sumo reduced numbers by 82%.

Further investigative work was carried out on soil samples from two of the sites, taken at sequential depths on a weekly basis at four 30 mm graduations to 120 mm (Figure 4). These samples were taken to NIAB at East Malling where the csfb pupae were extracted by floating them from the soil in water baths. The heatmap (Figure 5) shows that the majority of the pupae were in the top 30 mm of the soil which is very useful when looking closely at the actions of different cultivators.

This is the second year that NIAB have used this method and in both years, there has been a significant reduction in the number of csfb adults emerging from the soil. This project officially ended at the end of 2023 but NIAB is actively seeking funding to continue the work.

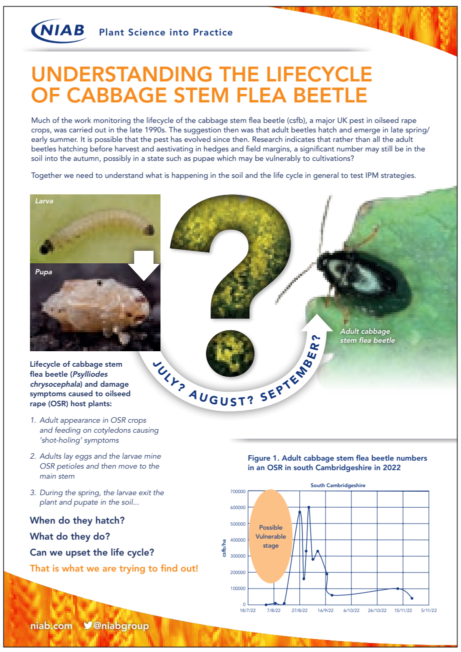


Figure 3. Cabbage stem flea beetle adults emerging from the soil after cultivations in north Hertfordshire

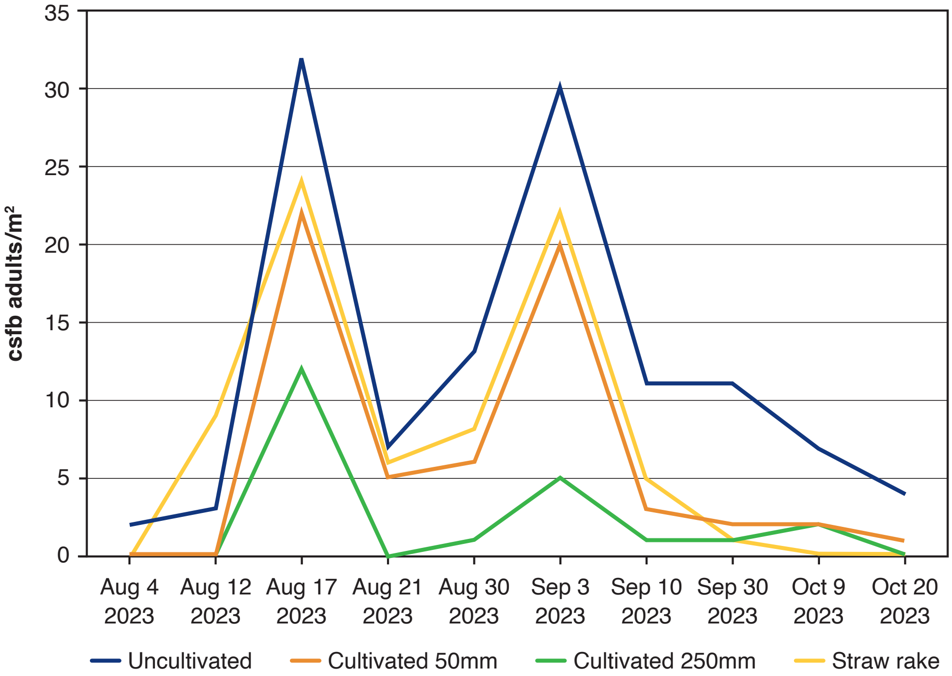


Figure 4. Schematic of soil sampling depths

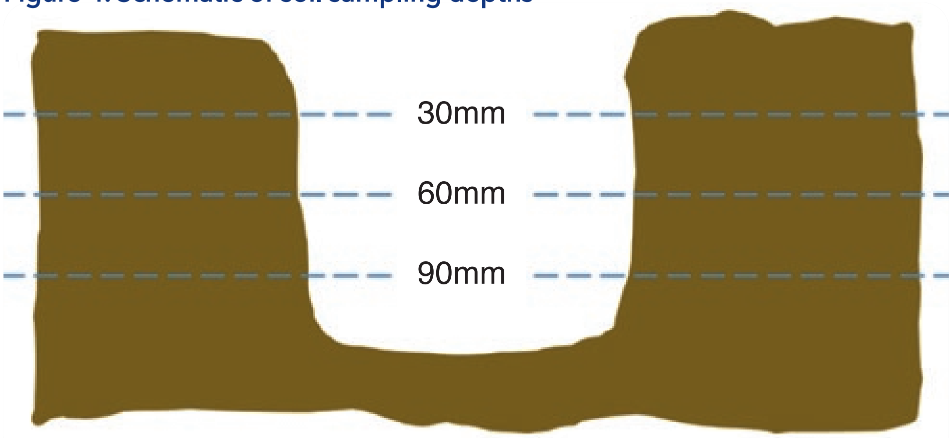
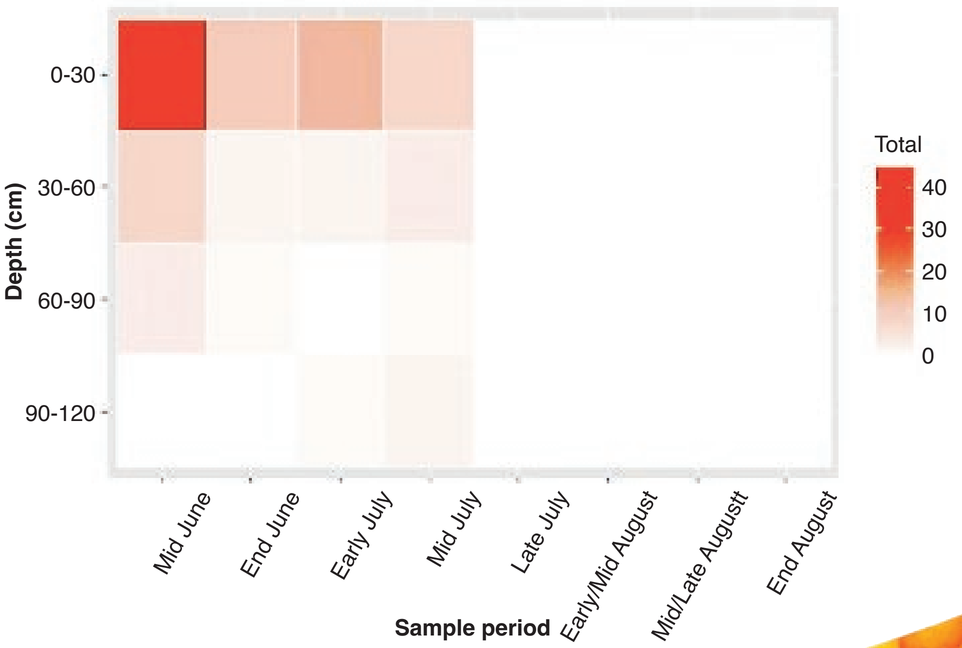


Figure 5. Heatmap of cabbage stem flea beetle found at different depths



ARTIS

Technical Training Courses

NIAB

Classroom Courses 2024

25 January	**Optimising crop management of leafy salads** • Trained by Liz Johnson • NIAB HQ
6 February	**Optimising nutrient management for combinable crops** • Trained by Andrew Watson • NIAB HQ
7 February	**Essentials of good soil management** • Trained by Nathan Morris • NIAB Park Farm
13 February	**Advanced nutrient management for combinable crops** • Trained by Stuart Knight • NIAB HQ
27 February	**Gross margin budgeting and management** • Trained by Chris Winney • NIAB Park Farm
29 February	**Advanced disease management and control in cereal crops** • Trained by Aoife O'Driscoll • NIAB HQ
5 March	**Measuring and monitoring potato crops for enhanced crop performance (pm)** • Trained by Sarah Roberts • NIAB HQ
6 March	**Understanding and optimising potato nutrition (pm)** • Trained by Elizabeth Stockdale • NIAB HQ

Virtual Courses 2024

30 January	**Techniques for better pest management in combinable crops** • Trained by Phil Humphrey
31 January	**Advanced crop management of bulb onions** • Trained by Andy Richardson
8 February	**Exploring regenerative agriculture** • Trained by Elizabeth Stockdale and Richard Harding
14 February	**Disease management and control in cereal crops** • Trained by Aoife O'Driscoll
15 February	**Improving soil organic matter and farm carbon management** • Trained by Elizabeth Stockdale and Becky Willson
28 February	**Best practice onion storage** • Trained by Andy Richardson
7 & 8 March	**Benefits of cover crops in arable systems** • Trained by Nathan Morris

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Discovering Agritech

Landmark's **Discovering Agritech** feature shines a spotlight on the projects and businesses working with NIAB to offer innovative and sustainable solutions to the food and farming sector, both in the UK and globally.

Two enterprises are featured in each issue, giving them an opportunity to outline their vision and plans for new products and services – for this issue we welcome **Petiole** and **Verdant Carbon**.

Through initiatives such as Barn4 and Growing Kent & Medway, NIAB is committed to creating, developing and supporting new commercial activity across the agricultural or horticultural sectors. Delivery is through licenses, consultancy, access to facilities, training and agritech products or services and across our activities we are able to reach into NIAB's global industry networks, its science, and its talent pool to access the resources and skills we need.

Developing mutually beneficial relationships with small and medium-sized enterprises (SMEs) and their investors in the agritech sector is an important focus for NIAB, working closely with the sector to explore new business models and support delivery of innovation for the industry.

Providing AI solutions to industry

Tell us about your company, what it does and what are you trying to achieve?

Petiole is a UK-based, female-led company that has developed a mobile-first platform offering a selection of pre-existing use cases of applying AI in agriculture, forestry, and aquaculture. A 'use case' refers to a specific problem addressed by our platform. For instance, if a user needs to measure leaf area, our app can assist. Alternatively, if a user needs to assess the nitrogen status of a plant, we have a module designed for that specific use case, and so on. We have been recognised for our innovation, being a finalist in the 2015 U.S. Department of State's Global Innovation through Science and Technology (GIST) initiative Tech-I Competition and winning the Global Alliance Africa Innovation Challenge in 2022.

Our mobile application has been cited in over 80 research papers, published by plant scientists from 30 countries in Frontiers in Plant Science, MDPI Plants, Microorganisms, etc. Petiole is a member of Barn4 and a participant of Barclays Eagle Labs AgriTech Bridge Cohort 2023. We have also been a pre-selected participant in UK agri-tech missions to Canada, Colombia, the Netherlands, and Germany.

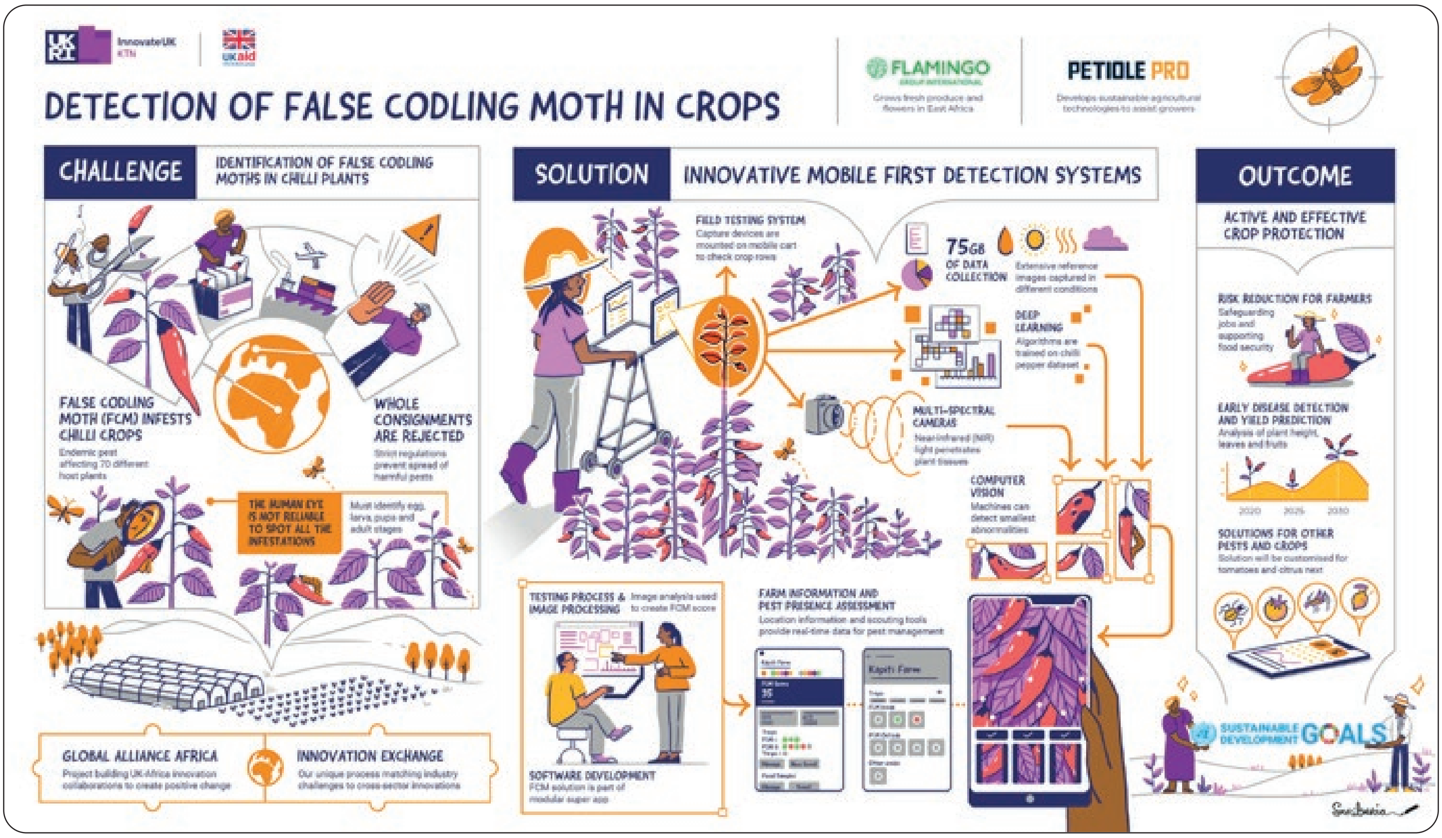
Petiole is a part of the current cohort in the Singapore-based GROW Accelerator Programme, funded by Innovate UK. Our mission is to introduce our smartphone-based platform to every research lab worldwide.

How does your product/service benefit the agriculture industry?

Our smartphone-based platform, Petiole Pro, streamlines the process of plant phenotyping and post-harvest quality assurance of food produce, enabling

A recent study investigated how various seaweed liquid extracts (SLE) can significantly enhance the growth, metabolism, seed germination, and overall yield of **Tomato plants** (*Solanum lycopersicum*)

quick, precise, and scalable analysis. We offer a selection of use cases for leaf area measurement, dark green colour index (DGCI) assessment of leaf greenness, counting root nodules, seedling counts, and other tools. This precision of our AI technology aids in better understanding of plant health and growth, directly impacting crop management strategies in multiple ways. For example, we support conventional agricultural producers in their need to develop more sustainable methods of using compounds such as pesticides and stimulants on plants, and we are simultaneously



supporting regenerative agriculture and the need to breed crops with the highest carbon sequestration characteristics. We are delighted our smartphone app, Petiole Pro, can be use by a varied group of customers who all have the same goals of creating food security and protecting the natural environment.

How are you working with, or supported by, NIAB?

We participated in various activities at Barn4, ranging from the Meeting of Minds to Fruit Focus 2022. At NIAB, we worked for a short period on a module for counting strawberry flowers as part of yield forecasting. We also applied for a grant as part of a consortium to develop new varieties of winter wheat, which aimed to assess the nitrogen status of crops over two seasons using RGB and NIR imagery.

Why did you join Barn4? How important have they been for developing and supporting your start-up?

We joined Barn4 in early 2021, and it has been our pleasure to be one of the oldest members of NIAB's innovative agritech incubator. We have received excellent support from Barn4, including being introduced to new potential customers and partners, and in sharing information about various opportunities for collaboration through informative communications. We appreciate the connectivity of Barn4's extensive global network of agritech startups and companies, and we are excited to continue to drive innovation and growth within the agricultural technology sector together.

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Delivering soil carbon measurement services

VERDANT CARBON

Tell us about your company, what it does and what are you trying to achieve?

Verdant Carbon provides sampling and analysis of soil carbon and soil health to farmers and was established in response to the rising demand for accurate carbon measurements and standardisation in agricultural practice. Farmers are under increasing government pressure to address climate change. We provide farmers with accurate and reliable measurements of soil carbon as a tool that is necessary to understand how their soil management practices impact soil health and soil carbon capture. This will help farmers to improve their environmental impact more effectively.

How does your product/service benefit the agriculture industry?
Soils have significant potential to sequester atmospheric carbon depending on how the soil is managed. Only through reliable measurement systems can we hope to understand what optimum soil management should look like on each farm. The pace of capturing soil carbon may be gradual, but the changes to soil carbon can be measured in an affordable, standardised, and rapid way. Repeated soil carbon and health assessments (carbon baselining) can quickly reveal how small changes to soil management translate to carbon capture capacity. This is valuable information for any farm as it establishes a record of carbon sequestration to support the development of best agronomic practice on farms.

Standardising a method for measuring carbon capture by soils will enable better comparison of farming practices and promote widespread adoption across the industry. Providing greater knowledge of the soil microbiome (the microbiological activity within the soil) will enable farmers to better understand and plan soil management practices. Together, carbon and microbiome assessments provide a robust tool which can support and encourage farmers in their climate transition.

How are you working with NIAB?
We were awarded a Business Innovation Voucher from Growing Kent & Medway, which funded 75% of our project with NIAB. Our project aims to understand the relationship between the soil microbiome and soil carbon. As a company we are particularly interested in organic carbon which is most affected by farming practices and consists of a variety of nematodes, protozoa, bacteria, fungi and more. We sample and geotag soils on farms down to one metre depth (subject to soil conditions). The metre is divided into three different sections, allowing for a detailed assessment. These samples are then analysed for total, organic and inorganic carbon using a technique known as Dumas Dry Combustion.

NIAB are taking a proportion of the samples and analysing bacterial and fungal microbial diversity using a hi-tech DNA sequencing approach. The aim of this is to find patterns between soil carbon content and the microbiome which will allow farmers to enhance levels of carbon sequestration through improving their soil microbiome and facilitate their journey towards achieving net-zero emissions.

Why did you join Growing Kent & Medway? How important have they been for developing and supporting your start-up?
Partnering with Growing Kent & Medway has allowed our fledgling company to expand its connections with researchers, such as those at NIAB. The research at NIAB encompasses a diverse range of cropping systems, including commercial orchards, arable regions and forestry areas. The extensive dataset derived from this research will hold great value for the improvement of soil management practices.

Despite soils being vitally important on several levels, their biological complexity remains poorly understood. Our Growing Kent & Medway funded work aims to bridge the knowledge gap providing farmers with a greater understanding of enhancing carbon sequestration.

Verdant Carbon Ltd

Frank Gollins – co-founder and carbon market director

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Carbon capture cropping

Reducing greenhouse gas (GHG) emissions, and improving resilience to climate change and extreme weather, are global challenges for farming and land management. On 20 September 2023, the UK Prime Minister Rishi Sunak recommitted the UK to achieving Net Zero by 2050, saying; "This means that the total greenhouse gas emissions would be equal to the emissions removed from the atmosphere, with the aim of limiting global warming and resultant climate change."

The goal for UK farming is, however, to reach this milestone ten years earlier. According to the UK Government's Agri-climate report 2022, GHG emissions from UK agriculture in 2020 were 44.8 $MtCO_2e$ (metric tonnes CO_2 equivalent), or about 11% of the UK's total GHG emissions. We can be under no illusion, therefore, as to the extent of progress that is needed over the next two decades to achieve Net Zero. The 2022 Farm Practices Survey indicated that 64% of farmers thought it 'fairly' or 'very important' to consider GHGs when taking decisions about crops, land and livestock; but the same survey revealed that only 44% believed that reducing GHG emissions would contribute to improving overall profitability.

Intergovernmental Panel on Climate Change (IPCC) estimates suggest that global soil carbon sequestration in agricultural land has the potential to mitigate GHG emissions of up to 5.3 $GtCO_2e$ per year, although it would not be cost effective for farmers to achieve this level. Uncertainty remains about how much carbon can be captured and retained through changed practices (for example: modified rotations, cover cropping or direct drilling), how long it can be sequestered in the soil, and how we can accurately measure and track the carbon. Furthermore, there is a limit to how much can be captured in soils before they become saturated, which varies according to soil type.

There is no shortage of optimism around the world on the potential offered by soil carbon sequestration. A recent paper by Professors Jacqueline McGlade (carbon sequestration champion for the UKRI Sustainable

Dr Lydia Smith is the project leader for the Centre for High Carbon Capture Cropping (CHCx3) project and Head of the knowledge transfer platform NIAB Innovation Farm. She has more than 35 years' experience in farmer and industry-facing crop diversification and improvement, grounded in soil-crop- microbial interactions.

Stuart Knight, Director of Agronomy at NIAB, has more than 30 years' experience across many aspects of combinable crop agronomy research and knowledge exchange. Stuart leads the Knowledge Hub workstream for the CHCx3 project.

Jasmine Toole is the soils technical lead and knowledge exchange coordinator on the CHCx3 project at NIAB. Jasmine recently graduated from the University of Warwick with a MSc in Sustainable Crop Production with a focus on soil health.

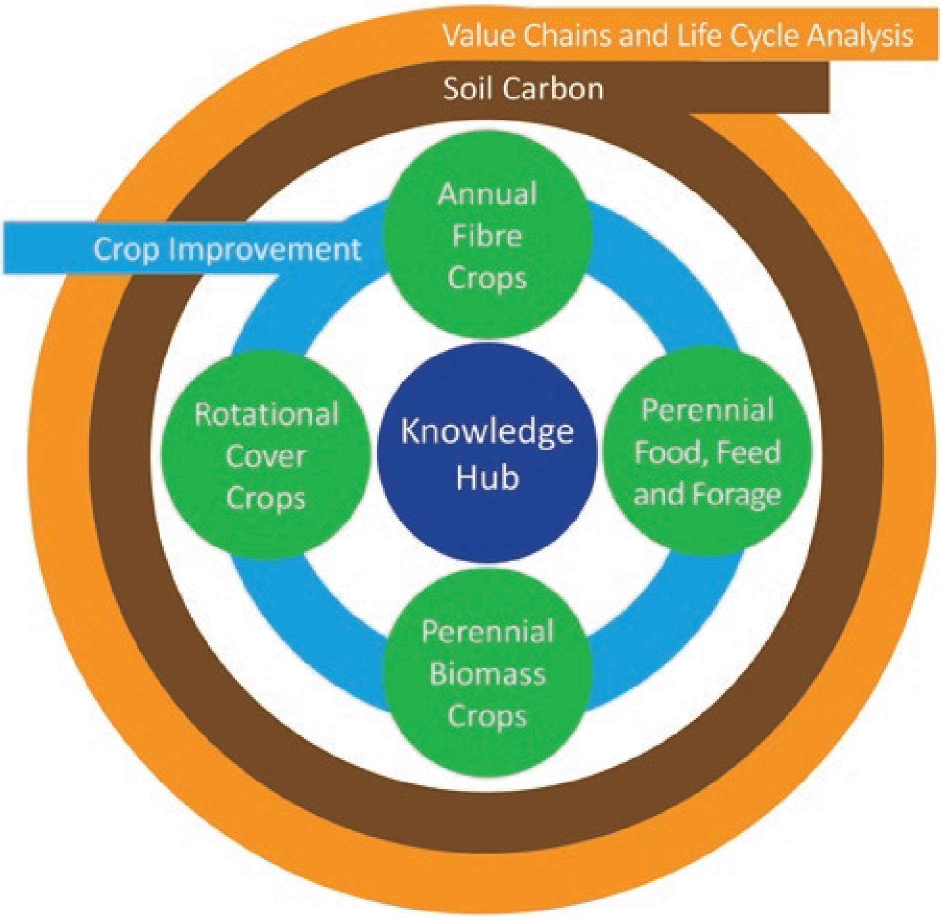
CENTRE FOR HIGH CARBON CAPTURE CROPPING

UKRI Innovate UK

Industrial Hemp

Agri-food for Net Zero Network+) and Kevin Morris of UCL suggested that increasing average soil organic carbon in land under crops or pasture by 1% globally would be sufficient to capture about 311 $GtCO_2e$; delivering eight years' worth of the reduction needed in predicted 2030 global GHG emissions in

Figure 1. CHCx3 Workstreams



order to limit global warming to 1.5°C. Carbon credits awarded for carbon sequestration form an important part of Australia's plan to achieve Net Zero by 2050 under the Australian carbon credit units scheme, and similarly under the bipartisan Growing Climate Solutions Act in the US, where the Biden-Harris Administration has committed the USDA to investing $300 million through the 'Investing in America agenda' to improve measurement, monitoring, reporting and verification of greenhouse gas emissions and carbon sequestration in climate-smart agriculture and forestry. Meanwhile, it is reported that FTSE 100 companies are amongst those looking to invest in soil carbon measurement.

Whatever the reality, soil carbon sequestration can only form part of the solution, and we also need to look at other ways to capture carbon through cropping. Current UK arable and forage cropping are dominated by relatively few crops, largely grown as monocultures. This is a risk to sustainable agricultural productivity, with the threat from, or deteriorating ability to deal with, pest, weed and disease pressures. Alternative, input-efficient cropping options could increase carbon-capture not just in the soil but also locked up in biorenewable materials. This potential for crop diversification helps both farmers and associated industries make progress toward Net Zero. Achieving profitable, sustainable outcomes, whilst minimising the negative and maximising positive impacts that farming has on the environment, requires a concerted effort. From the outset, this needs to involve the many other industries that form part of food, fibre, and biomass value-chains.

The Centre for High Carbon Capture Cropping (CHCx3) is a four-year, £5.9 million project, led by NIAB, with partners spanning agriculture, industry, and academia. The project, which started in April 2023, aims to:

- help UK growers capture more carbon and build farm resilience through diversifying their cropping;
- enable insetting/offsetting of emissions and offer new revenue sources in the carbon market;
- support enhanced value chains for industries such as textiles and construction using biorenewables.

CHCx3 was awarded funding by Defra under the Farming Futures R&D Fund: Climate Smart Farming, part of Defra's Farming Innovation Programme delivered in partnership with Innovate UK. The research (Figure 1) considers the role of four cropping options and their associated tillage systems: rotational cover crops; annual fibre crops (industrial hemp and flax); perennial

Harvesting Miscanthus

Herbal Ley

food, forage, and feed (in particular, enhanced biodiverse leys and perennial cereal); and perennial biomass crops (miscanthus, willow and poplar). In addition to evaluating their potential to enhance atmospheric carbon capture, and its sequestration in the soil and/or crop-based products, field trials will examine the effects of growing system on economic returns and environmental outcomes.

The project is active in:

- building value chains for optimised production and use of renewable biomaterials for fibre, textiles, construction, or manufacturing, and better understanding their life cycles;
- quantifying carbon removals, consistent with emerging standards for measurement, monitoring, reporting, and verification;
- developing a platform for tracking soil carbon, to facilitate insetting or offsetting of emissions, enable new revenue opportunities for farms, and support corporate sustainability goals;
- evaluating new varieties and traits for UK farmers.

We are developing a molecular breeding platform for industrial hemp and assessing the development needs of other crops within these categories.

To aid translation of the research into practice, CHCx3 has established a UK Knowledge Hub that will provide resources to support farmers, agronomists and landowners in the successful uptake and utilisation of crops with high carbon-capture potential, including practical outputs such as crop guides, web tools and apps. We are also growing a community of growers, agronomists, crop scientists, plant breeders, crop processors, product manufacturers, environment organisations, and policymakers, all with an interest in high carbon capture cropping. Throughout 2024 there will be opportunities to engage with the research and project partners, and to participate in free events. Two short webinars have already been delivered with more to follow in 2024.

CHCx3 Project Partners

NIAB, Biorenewables Development Centre, British Hemp Alliance, Cotswold Seeds, Crops for Energy, Elsoms Seeds, Energy Crops Consultancy, English Fine Cottons, FarmED, F C Palmer & Sons, National Farmers Union of England & Wales, Natural Building Systems, Northern Ireland Hemp Association, Rothamsted Research, Scottish Hemp Association, Terravesta, UK Hempcrete, University of York, Unyte Hemp

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Dr Ellie Sweetman is NIAB's forage crop specialist, managing the statutory and commercial forage crop trials programmes alongside providing technical and scientific knowledge on forage crops to NIAB members, APHA, seed companies, commercial businesses and educational organisations. She works with industry in developing research and training projects alongside contributing to NIAB's agronomy guides and publications.

Investigating opportunities to increase carbon capture in grasslands

As part of the ongoing Centre for High Carbon Capture Cropping (CHCx3) project, perennial food, forage and feed crops, NIAB is investigating opportunities for increasing carbon capture in different types of agricultural grasslands.

Grasslands are potential carbon sinks, helping to counteract increases in atmospheric CO_2 but the complexity of the processes involved in carbon capture and sequestration and the variable rates of carbon sequestration in UK grasslands are very difficult to determine, ranging from negative/loss to over eight tonnes of carbon sequestered per hectare per year. This is largely due to climatic variables as well as frequency, intensity and type of defoliation; plant species; soil type/texture; the type of carbon inputs; rate of decomposition of soil organic matter; sward condition; amount/duration of rainfall and prolonged periods of high temperatures and the timing of management practices.

Most of the carbon in grasslands is held in the roots and rhizosphere. Root exudates supply a highly diverse range of soil microbes, initiating symbiosis between plant roots and mycorrhizal fungi and altering the soil biological, chemical and physical properties. These exudates supply carbon in various forms into the soil food web as well as the carbon released through root biomass turnover and decomposition, all of which are influenced by grassland species, grazing method and addition of manure. Both overgrazing and under-grazing/infrequent cutting can reduce soil carbon stocks in grasslands as excessive defoliation frequency can result in root dieback, whilst under-grazed swards may have reduced activity in the rhizosphere.

Increasing grassland biomass through improved management can sequester considerable amounts of carbon but there are associated emissions from the inputs and fossil fuel use that must also be taken into account and the effects of management on soil carbon sequestration and emissions of cultivated grasslands are, as yet, poorly understood.

Cultivation and reseeding of grassland makes the soil organic matter vulnerable to carbon loss compared to permanent pasture. Highly productive grass-clover swards store carbon but around 20-30% of the carbon in the top 30 cm of the soil is susceptible to rapid losses from frequent cultivation if reseeding is done regularly.

Carbon is stored in a range of compounds and organisms throughout the soil food web and these respond differently to different types of management.

Grazing has been found to accelerate annual shoot turnover, add organic carbon through animal excreta and redistribute carbon through the rhizosphere compared to ungrazed swards. Sites with no grazing often have lower root density. Exclusion of grazing can lead to immobilisation of carbon, reduced growth of fibrous roots and therefore reduced carbon stocks but again this depends on soil type, climate, sward composition and use of fertiliser.

Many permanent pastures and temporary leys also contain other perennial grassland plants, which have different rooting patterns and different root carbon and nitrogen interactions, adding further complexity.

Recent studies have found increases in soil carbon in temperate grasslands of 14% can be achieved from a single improvement (such as fertilisation or introduction of a legume), more work is needed to understand the accumulated effects of multiple improvements and associated emissions must be taken into account but we are aiming to provide some straightforward recommendations of management practices and timings that will support increased carbon capture for different grassland types and uses for UK farmers by the end of the project in order to help farmers develop suitable management strategies, particularly in response to changing environmental conditions.

From the findings on the CHCx3 project so far, areas needing further investigation include; the soil and plant interactions of carbon and nitrogen in different types of grassland; the mechanisms which influence carbon storage and turnover in both fertilised and unfertilised grasslands and the potential contributions from legumes within the swards.

Further investigation and understanding is also needed of the significance of microbial diversity in grassland soils, the rate of turnover of differing soil carbon compounds and soil carbon stabilisation in different grassland systems.

Board profile – David Buckeridge

Dr David Buckeridge became Chair of the NIAB Board in June 2023, bringing 40 years of operational management experience in the life science and agribusiness industries to the organisation. NIAB Landmark finds out a little more about David, his career and his aspirations for NIAB.

NIAB CEO Mario Caccamo, David Buckeridge and former NIAB CEO Jim Godfrey

Would you tell us about your background?

Originally from west London I studied agricultural botany at Aberystwyth University, despite no agricultural background. But, I enjoyed biology and chemistry at school, appreciated the practical and useful application of science rather than a straight academic route, and wanted something different to my suburban upbringing; with the added benefit of lots of rugby. I followed up my degree with a PhD in plant genetics, which conclusively proved that R&D was not for me.

My career has never followed a set plan; I don't think that happens to many people. But I have been fortunate to have a wide and varied career with many opportunities. Post-PhD I joined ICI, one of the leading UK companies at the time, as a management trainee in its Plant Protection Division. I was given a product manual, a car and sent to Cornwall as a crop protection salesman. And that's how I started in agriculture. It was the perfect training and I learnt a lot from those farmers. I then spent the next 20 years in a variety of management positions, both in the UK and globally, within ICI; a company that eventually became AstraZeneca and finally Syngenta. This included running its global plant biotechnology division in the early days of GM. This was a huge research programme, competing with the life science companies such as Monsanto, Bayer and BASF in genomics and molecular technologies.

AstraZeneca was the joint owner of a global seeds company called Advanta. It was a great company, selling over €600 million of seeds across 70 countries. In 2004 I led it into private equity ownership, and then sold it, including its successful initial public offering (IPO), to the Indian stock market in 2007. After that, and more than a decade working for a financial institution, the global COVID pandemic allowed me time to realise I wanted to return to the life science sector, particularly both plant sciences and pharmaceuticals. So, I now provide advice to both strategic and financial investors in the life sciences and agribusiness, focusing on the operational and strategic planning aspects of these industries. I'm currently Chair of the Board of Protealis and of Cycle Pharmaceuticals in Cambridge, an independent director of Velcourt Ltd and on the boards of several companies within the agritech sector.

Why did you become involved with NIAB?

I'm passionate about the practical application of technological innovation; putting it in the hands of users, in this case farmers, in a way they can benefit from it. We can't waste money and time on things that ultimately don't work in practice and you can't take a random guess at what will work. And it has to be underwritten with evidence and trials and data. But agriculture moves slowly. It takes time to do these experiments. We need proper trials. We need replicated trials. We need data to help make decisions.

And NIAB has always been the key to achieving this. It is the perfect interface for all these required technologies; a central point. We need a translational science institute like NIAB, sitting "downstream" of pure academic, blue-sky institutes and universities and the vital role they play. We must provide the support for farmers in turning that technology into something that secures our food supply, secures the health of our environment, and secures the carbon in the soil. That's such an exciting place to sit and why I was very keen to get involved with NIAB.

What do you see as the big challenges facing the UK food and agriculture sector?

I've had a 40 year career in this industry; I joined at a time when we were in a productivity boom where we needed more food and had to increase productivity. We used science to help us do that with new chemistry, improved crop genetics, and better technology. We fed millions of people around the world who may not have had food without the amazing innovations that were achieved.

And we still need to produce healthy, nutritious, safe food for people, at a price they can afford. Which means we need further advancements to improve food security, the way we produce food, and of course, protecting our climate and improving biodiversity which may have been overlooked 40 years ago. But productivity is key; yields must increase.

Having great and innovative ideas is essential. We cannot go backwards and farm as we did 50 years ago to solve our problems. We have to go forwards by adopting and translating innovation. We need another agricultural revolution.

But telling people to just adopt new

practices without the evidence risks that in five years time we find they didn't quite do what we thought they were going to do. But can we afford those lost five years? So, it means helping and supporting farmers. They are the practitioners on the land that will sequester the carbon, who will give you economically produced food of high quality without damaging the landscape. We have to facilitate that, by underpinning it with science and support. This is not a case of organic versus conventional, of biological control versus chemical control. That's all very easy to say, but is not easy on farm. We need to learn how to use all the tools available to us appropriately. There is no shortcut.

What are your ambitions and vision for NIAB?

NIAB is absolutely the right place to drive this new revolution. It has the skill set, the technology, the people and the assets. It is already working in so many areas that are at the heart of new revolution, including crop transformation expertise, improved crop genetics research, strategic input advice and regenerative agriculture management practices. It just has to be enabled to get that work done and out onto farm, including support from Government. The policies are there but the execution has to be better.

And NIAB could do a lot more; it is our time. We have to push barriers because we urgently need to address these global challenges of food security, climate change, sustainable resource use and the production of healthy and nutritious food. We have to be prepared to stand up and be counted and say what sometimes might be unpopular.

The 'not-for-profit' philosophy is very different for me. I'm a profit and shareholders guy so I'm very interested in how we can combine the two concepts and make it work better for NIAB. What I find exciting is that if we do well and that generates income for the Institute – every penny goes back into plant science! So when some of the leading agribusinesses in the world work with us (as many do), they can know that every penny they commit to us will be turned around to further the products, systems and services on which their businesses depend – we might even develop some products they can sell!

Getting to know you

What was the last book you read?

I'm not a voracious reader, preferring to be out and about and active. But I do enjoy current affairs and autobiographies. I am currently reading 'Red Notice' by Bill Browder, a former hedge-fund manager who tried to invest in public Russian companies in the 1990s and then found himself blocked by the Russian oligarchy and eventually by Putin. It's a very tense, interesting book covering the corruption in modern Russia.

Which is your favourite sports team?

I'm a sports fanatic and enjoy watching and taking part in all kinds of activities. As a family we sail a lot; we live on the Isle of Wight and often go on water-based holidays. I've been a West Ham United fan since I was seven years old; it has been extremely stressful watching them systematically fail every year, except last season where we won the Europa Conference League. I'm a huge cricket fan and will always have Test Matches on in the background. And with two sons and two daughters I've spent an awful lot of time on the touchline of various school matches across the years, particularly hockey.

Where's your favourite holiday destination?

Anywhere warm where we can be on, or in, the water, particularly sailing, and where we're altogether as a family. We haven't spent Christmas in the UK for a very long time, and love exploring the Caribbean; Antigua, British Virgin Islands, Granada, and Barbados. But this year we're heading to the Indian Ocean and going to Mauritius. And the mountains are great for activity holidays. This summer we spent time in the French Alps, hiking and biking but we also enjoy skiing in the winter.

Tell us something about you that would surprise people?

My guilty pleasure. I do enjoy watching reality TV especially Below Deck, but also Made in Chelsea and Love Island.

If you hadn't worked in agri-business, what else would you have done?

I always wanted to work in life sciences and didn't really consider anything else, although I did love history at school. I could have gone down the medical route, but ended up in food and agriculture. However, a few years ago, as my career changed, I did consider taking a degree in marine biology; the sea is such an important part of our family life – I recently started working with a seaweed company in Norway, and I'm just fascinated with it.

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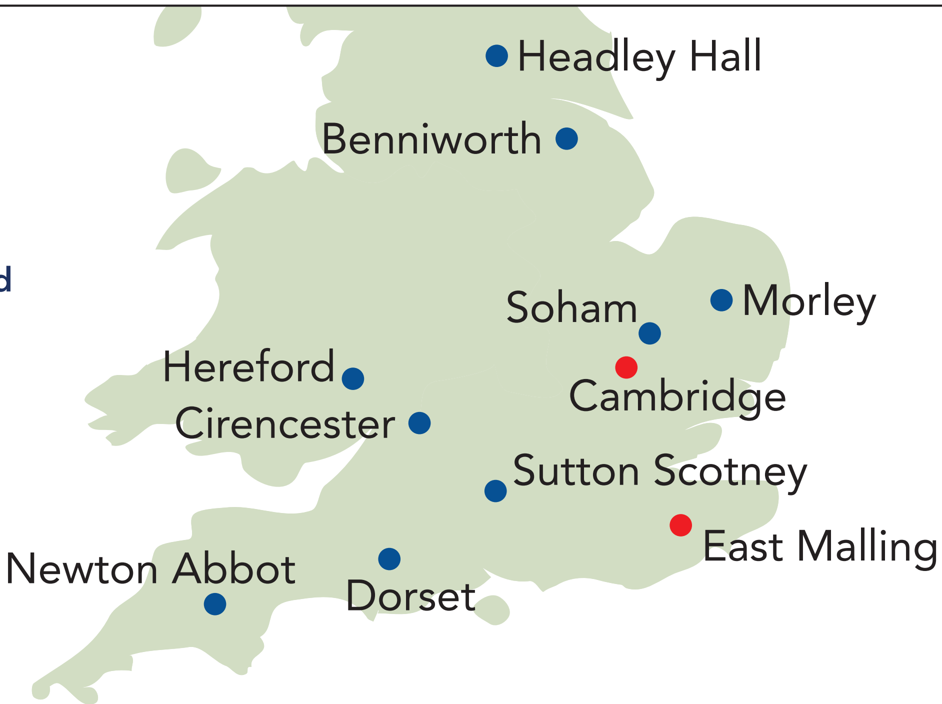

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