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Landmark

The science of regenerative agriculture

In this Issue

REGENERATIVE AGRICULTURE SPECIAL

2019

2019

2019

1994

1994

Her Majesty Queen Elizabeth II

1926-2022

Since its foundation by a Deed of Trust in 1919, NIAB has been honoured to have Royal support and we are immensely proud that The Queen was our Patron for the past 70 years. Her Majesty visited NIAB three times during her reign, joining us to celebrate our 50th anniversary in 1969, our 75th in 1994 and then most recently to celebrate NIAB's Centenary in 2019. She showed immense interest in all the work she viewed and her tree planting skills, even at 93 years old, made headlines across the world.

The Queen's sense of duty has been, and will continue to be, inspirational to all of us. RIP Ma'am.

Professor Mario Caccamo, CEO, NIAB

2019

1969

1969

1981 – the NIAB stand at The Royal Show

Mario Caccamo, Chief Executive, NIAB

A science-led approach to regenerative farming

Last December we welcomed at our headquarters in Cambridge a group of farmers representing MAIZALL. This is an alliance of growers from Argentina, Brazil and the United States – the three largest exporters of maize in the Americas. They described how advances in genetics and agronomy in the past 20 years have helped farmers in the group to increase yields per hectare, reduce the use of plant protection products and in this way conserve biodiversity of the soil and the environment.

MAIZALL growers avoid tilling the soil, resulting in fewer field passes and operations with machinery, leading to reductions in fuel use which impacts both cost and CO_2 emissions. These are family businesses, and for these growers soil health is a priority as they look to future-proof their land for generations to come. As they made it clear, they make use of every tool in the toolbox.

Regenerative farming is used to describe integrated approaches to agriculture with a focus on improving soil health. At NIAB, we have worked on such approaches for more than 15 years, and this special issue of Landmark highlights some of that research and advice. Although we are agnostic about how they are labelled, our research is designed to support informed decisions for all growers looking at enhancing soil health, whilst raising productivity and promoting ecosystem services such as biodiversity. NIAB's role is to provide independent, science-based evidence to help evaluate practices and products. We learn from experiments that are designed robustly, and from both successes and failures.

John Pawsey

Winter wheat and field beans bi-cropping

Complexity

The soil is a very complex system, and we are only just beginning to understand how to manage it optimally for the future. A handful of soil contains millions of organisms, from viruses to bacteria to fungi, that compete and co-exist with a large number of invertebrates. Recent advances in molecular biology have expanded our ability to measure and characterise the species we find in the soil which is only the first step to be able to assess and compare soil health.

Soils are also highly variable; properties such as organic matter content, available nutrients and pH exhibit a wide range, at times even within a single farm. Therefore, an effective approach to preserving and improving soil health will need to be locally-adapted, making use of all the tools and technologies available to us.

We should consider, for instance, the potential for novel crop varieties generated using cutting-edge breeding technologies. Developing crops that utilise nutrients more efficiently or that can use less water will be key to bringing regenerative farming at scale to address the challenge of food insecurity whilst protecting the soil and other ecosystem services. If the aim is to promote more efficient and precise production while maintaining a healthy soil, regenerative farming cannot exclude the use of new breeding technologies, on the contrary!

In the on-farm research programmes at NIAB, we also study the use of our land and the impact that agriculture has on the environment. One example is the work we carry out on tillage practices to improve sustainability and reduce soil carbon losses as greenhouse gases. We investigate solutions that will keep the soil surface covered as much as possible by integrating catch, cover and intercrops within the rotation. We have examples of projects in this space on different soils and looking at different farming systems, as showed by the articles in this issue.

Legumes

There are also opportunities to widen the options for current rotations. As we look to reduce the inputs from fertilisers, and also to increase plant proteins in our diets, we should consider the development of varieties of nitrogen-fixing legumes such as soybean and lentils that could be adapted to Northern European conditions. We should prioritise growing the UK's capabilities in the area of legume genetics, building upon a strong base of research and germplasm resources.

More broadly, approaches that combine biotechnology, genomic prediction, data science, crop breeding and agronomic expertise will be needed to design, implement and deploy crop improvement programmes at speed and scale. The new Precision Breeding Bill currently going through Parliament will provide a more straightforward route to market in England for seeds and crops developed using advanced breeding technologies such as gene editing.

The advent of agriculture 10,000 years ago was the most important development in human history upon which societies have flourished. Although originally edible plants were not suitable to feed a growing population, through the development of breeding we managed to domesticate them to increase yields and improve their nutrition.

The same principle applies to soil health and the need to optimise farming systems for carbon capture. We should firmly reject the voices making sweeping statements about the incompatibility of productive agriculture, biotechnology and regenerative farming. A science-led approach to assess the value of regenerative farming approaches will be the only way to ensure we can continue to feed the world whilst protecting the soil health and the environment. As the MAIZALL growers do, let us use all the tools at our disposal.

Elizabeth Stockdale • elizabeth.stockdale@niab.com

Regenerative agriculture – a new name for well-established practices

A research and knowledge exchange specialist with a focus on sustainable land use and management, Dr Elizabeth Stockdale is NIAB's Head of Farming Systems Research with over 25 years of applied soil and nutrient management research experience.

The use of the term 'regenerative farming' has recently come to the forefront of discussion about integrated approaches to farming that include a focus on improving soil health. As with all 'new' things in farming, many of the approaches and farming systems that the term describes have been studied and practiced for generations. Nonetheless the idea that agriculture needed a new revolution that regenerated soils, habitats and biodiversity, rural communities and, more recently, our climate, can be found in writings and reflection during the late 20th Century.

Approaches referred to as regenerative farming have been increasingly used in the online academic literature since about 2015, and in the UK the use of the term within the farming industry has also grown rapidly in parallel with the popularity of the no-till event Groundswell.

Many of the foundations of what is now called the regenerative agriculture movement can be found in conservation tillage systems, which combine zero tillage with increased soil cover (catch, cover and inter-crops) and largely originate in dryland systems where the risk of soil erosion was high. Within the broader framework of regenerative agriculture, these approaches have been brought together with practices from organic farming and 'holistic planned grazing' with the overall aim of developing farming systems that mimic nature, as much as possible. Regenerative farming systems often share common principles and systems-focused approaches.

In the classic formulation, seen on the Groundswell tea towel, these are given as:

- Keep the soil surface covered as much as possible;
- Try to limit the amount of physical and chemical disturbance of the soil as much as possible;
- A wide diversity of plants is encouraged to increase soil biodiversity;
- Keep living roots in the soil for as much of the year as possible;
- Integrate grazing livestock into the system.

More recently one of the most prominent US pioneers, Gabe Brown, has added a sixth principle, that of CONTEXT. This recognises that where principles are put into practice for any farming system, the first step is to know both the constraints and opportunities offered both by the site (e.g. soils, climate, hydrology) and also by the system (e.g. tenure, markets, risk profile) so that the most appropriate management options can be selected. Not all the principles will be fully present in every system. A key characteristic of regenerative systems is their diversity and flexibility, this results in marked local adaption of the system to its particular context, as well as season to season variability.

Regenerative systems should deliver measurable outcomes:

healthy soil, increased biodiversity, improved water quality and climate resilience, profitable farming systems

NIAB delivers a wide range of research in partnership with industry and other academic organisations, as well as through on-farm research and discussion with NIAB members. Our work with Groundswell, farmer pioneers of regenerative agriculture in the UK and our own farmer members, all of whom are seeking to explore and implement regenerative practices for cropping systems to underpin profitable and sustainable farming practice, has also led us to note that such farmers are also:

- focused on overall rotational margin, not individual crop yield,
- willing to experiment and learn from both successes and failures,
- actively engaged with the local community and the wider supply chain.

Because integrated cropping system science is still in its infancy, regenerative farmers are also often engaged in developing new monitoring systems e.g. use of BRIX, indicators of soil microbiology or testing new biostimulants and soil additives. NIAB has been actively involved in farming systems research for over 15 years with a large programme of work that has supported the development of regenerative approaches in the UK, including crop and variety selection, reducing cultivation intensity, effective integration of cover cropping, monitoring soil health, non-chemical weed control and approaches to integrated crop disease management aiming to optimise disease control through variety choice, cultural controls and targeted fungicide use. Some of this research is highlighted in the following articles in this Regenerative Agriculture special of Landmark.

Principles

In its Food Strategy, the UK Government has stated that it will develop a policy framework to broadly maintain the current level of food we produce domestically, including sustainably boosting production in sectors where there are post-Brexit opportunities including horticulture. The development of regenerative systems has been driven by combinable cropping, livestock and mixed systems. However, there is an urgent need to consider how the principles of regenerative systems can be adopted within vegetable and root crop rotations. The perception is often that the principles necessarily exclude root crops, but as formulated by the Groundswell event, the focus is on minimising tillage intensity and not necessarily removing all soil disturbance. Work in both potatoes and vegetable crops has shown that reductions in cultivation depth and optimisation speed can reduce fuel use and tillage intensity by more than half. Within the rotational context, these crops also provide a valuable break crop with distinct opportunities for weed control, as well as longer duration cover crops.

NIAB worked to support Unilever in the development of the Implementation Guides (Soil/Water/Climate) to support its regenerative agriculture principles. The *Unilever Regenerative Agriculture Principles* can be accessed online at https://bit.ly/3BKJiha.

Figure 1. Exploring the options for arable crop rotations (including root and vegetable crops); the positive impacts of practices for soil, water and climate (reduction in net farm greenhouse gas emissions) are highlighted

We reviewed the evidence of impacts for a wide range of practices and created an options framework for arable systems (including vegetables and root crops) that can support farmers and advisers in the selection of the most appropriate locally-adapted management options, as well as the best pathways to help redesign the cropping system without loss of profitability. As Figure 1 shows there are a wide range of practices that can be combined to deliver increasingly positive impacts on soil, water and climate; and when combined with appropriate habitat management steps are also likely to improve local biodiversity.

Long-term trials

An important part of implementing a new system, whether regenerative or any other, is collecting the information you need to be able to understand how successful it has been. However, system changes are often not very well suited to plot trials. NIAB has developed long-running farming systems trials that are now over 15 years old, where combinations of rotations and tillage systems are studied (NIAB's STAR and New Farming Systems research programmes). However, with regenerative systems, changes in tillage intensity and increased use of cover/catch crops are likely to be accompanied by changes in drilling dates, herbicide programmes, variety choice and many other things. Including all these factors individually in any trial would very quickly lead to a very large number of plots so we have been working with the University of Leeds to take a systems-focused approach to demonstrate and evaluate approaches to adopt regenerative systems.

NIAB has also been working with farmers on-farm to support monitoring of change. Indicators should be selected on farm to be relevant and directly linked and sensitive to the process under study, practical to measure, and easy to interpret. Observing and making notes on how well the processes have gone (any drilling issues, cover crop productivity etc) alongside weather and other seasonal factors is as important as outcome indicators such as yield or C footprint. For regenerative agriculture it is important to track impacts on soil, water, climate, biodiversity, productivity and profitability. The best records are kept through at the same site through time, but it is also possible to set up comparisons with other farmers operating on the same soil types.

As part of this systems approach, NIAB has launched a new Soils and Systems Monitoring project in the Wessex region in Autumn 2022. We will be working with three farms, from a broad spectrum of arable systems, to provide interesting comparisons across the breadth of management practices implemented locally. The Soils and System Monitoring project builds on on-going work that NIAB is delivering for AHDB's Strategic Farm South and will link soil health and yield data with the management practices implemented on members' farms.

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The management of soil health within cropping systems

This year has seen British records for heat broken for the second time in recent memory, and a dry growing season has affected yields, particularly in the south and east of the country. Challenging years may become more frequent as the effects of climate change impact temperatures and rainfall. There is therefore a need to adapt farming to these new and adverse conditions, a need to manage soil so that it can retain more organic matter and nutrients, and to improve its hydraulic functioning so that it can retain more water to sustain our crops, but also be resilient to heavy rainfall and flooding events. Many of the ideas within regenerative agriculture seek to address this, and indeed many farmers adopt regenerative agriculture for these reasons, but long-term trial data to back up the claims made by regenerative practitioners is somewhat lacking.

NIAB has been conducting long-term field trials to address these issues for many years. The STAR trial (Sustainability Trial for Arable Rotations) is a good example of this. Running since 2005 on a clay loam soil near Otley in Suffolk, the trial examines the effects of cultivation and rotation on crop yields and soil properties within conventional arable rotations. The trial is a factorial experiment with large 36x36 m plots with rotational treatments of winter cropping, spring cropping, alternate fallow and continuous wheat. On top of this, four tillage treatments are investigated, these tillage systems range in intensity from annual plough, deep non-inversion (20-25 cm), shallow non-inversion (ca. 10 cm) and a managed approach. The 'managed' tillage treatment is based on the soil conditions at the time of cultivation and field assessment data. The trial is maintained by NIAB in conjunction with an independent advisory group led by the host farmer, John Taylor. The STAR Project is supported by The Morley Agricultural Foundation and the Felix Thornley Cobbold Trust and, historically, The Chadacre Agricultural Trust.

In 2018, a new rotational treatment was incorporated into STAR to address growing interest around regenerative agriculture practices. A 'herbal' ley – a mixture of six grasses, seven forage legumes and five forbs (herbaceous species such as chicory) – replaced the alternate fallow treatment and was maintained for three years. The ley was allowed to grow and mown up to twice per year in June and September (depending on growth patterns), with all cuttings baled and removed. Many included species had deep roots which facilitated high biomass yields across all tillage treatments in dry years of 2019 and 2020. All leys were terminated in summer 2021 and returned to winter wheat, with all the pre-existing tillage treatments applied. The ley treatments were then split into two N treatments, one receiving farm standard 230 kg N/ha, and one a reduced rate of 140 kg N/ha. This was done to assess soil N availability following the cultivation of the N-fixing leys, and to assess the fertility-building legacy.

Dr Patrick McKenna at the 2022 STAR Open Day

Dr Nathan Morris is NIAB's farming systems and soils specialist, actively involved in knowledge exchange and farmer training activities. His particular interests and expertise include developing farming systems to improve soil structure and stability whist maintaining crop productivity.

Dr Joseph Martlew is a research agronomist at NIAB, with a mixed background in academia as a soil scientist and in industry as a commercial agronomist. He has a strong interest in how farm management approaches may be brought together into farming systems to increase the sustainability and resilience of food production.

David Clarke is the soils and farming systems technician at NIAB's Morley regional centre in Norfolk. He provides technical support to a range of research projects focusing on soils, crop rotations and farming systems.

Dr Patrick McKenna is an agronomist and soil scientist, interested in the effects of species diversity and grazing on forage production and soil quality, and how farmers can re-integrate herbal leys and sheep grazing into arable rotations.

Figure 1. Using CT scanning to understand the soil physical structure where a) is a plough cultivation in continuous wheat and b) is a shallow cultivation in alternate fallow

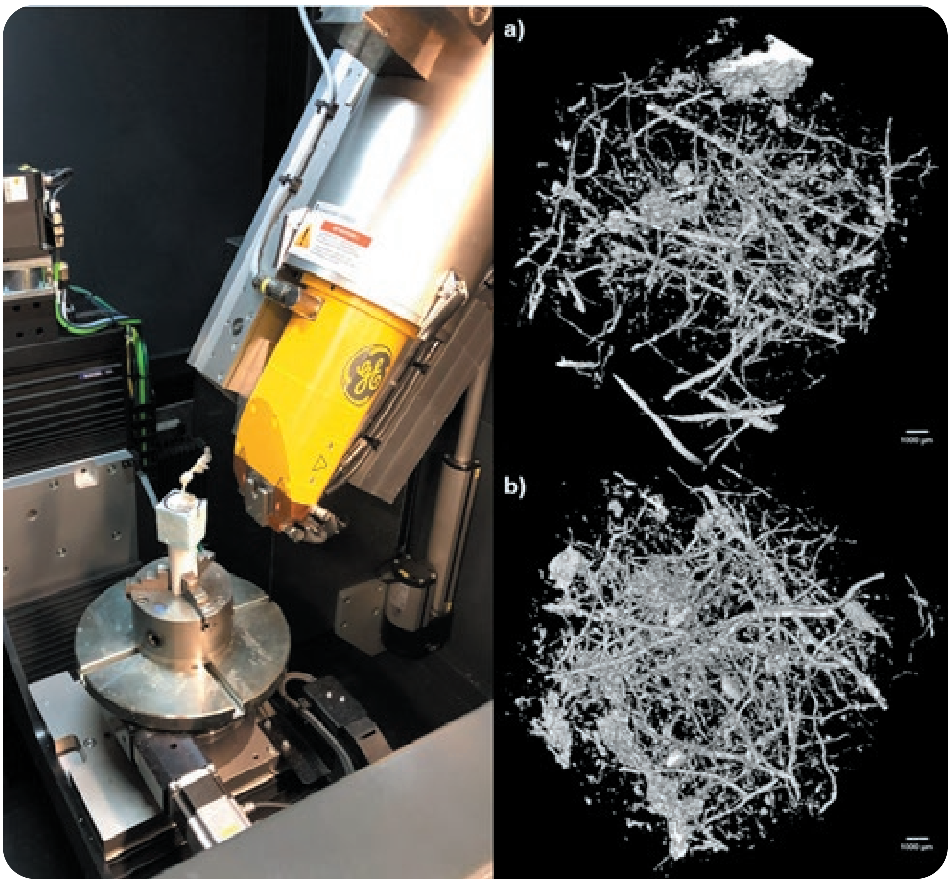
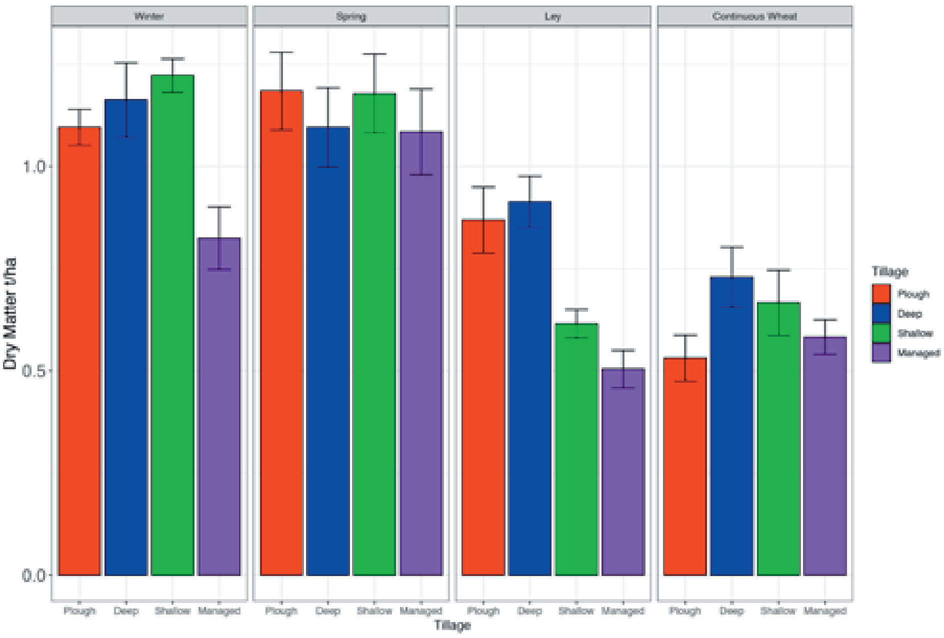


Figure 2. Effect of tillage and cropping system on wheat dry matter at GS 30

Winter, Spring and Continuous Wheat treatments received 220 kg N/ha, ley treatments received 130 kg N/ha



X-ray computed tomography was used to understand soil physical structure across the treatments (Figure 1). This technique allows the characterisation of soil physical structure without disturbing the soil sample. Results showed that reducing the intensity of cultivation (shallow, non-inversion) led to an improvement in soil pore volume, pore surface area and pore number. This benefit was maximised where low intensity cultivation was combined with alternative fallow and herbal ley rotation, where the greatest improvements in soil pore characteristics were recorded. Greater soil porosity and continuity are linked to lower compaction and improved soil function, and may support more sustainable and resilient crop growth.

Integrating herbal leys such as these into arable systems touches on many of the ideas found within regenerative agriculture. Increasing diversity within cropping systems can improve the soil microbiome and build climate resilience, whilst minimising soil disturbance and maintaining living roots in soil can build organic matter and reduce the risk of soil erosion. Reintegrating livestock grazing can also improve soil quality, and herbal leys provide excellent forage for livestock, but grazing was not applied to the STAR trial as the plots were too small to make it practical. We believe the performance of winter wheat crops following three years of ley, and the second wheat to be grown in 2022/23, will assess some of the claims around regenerative agriculture and climate adaptation, including fully costed appraisal of each system compared to more conventional practices

We have already had some interesting results from the wheat performance at STAR. Figure 2 shows the wheat biomass accumulated in all treatments at GS30. This data was taken in March 2022. Biomass at this growth stage is indicative of the availability of nutrients at the tillering stage, a time when plant N demand is high. This assessment was also taken just before the fertiliser was applied to all plots. Here we see the winter and spring cropping systems performing well, but the ley and continuous wheat systems are significantly lower. The continuous wheat system is not expected to perform as well as the other cropping systems, as the absence of crop rotation can reduce soil fertility and inhibit crop yields, particularly if practiced for as long as it has at the STAR site. The poorer performance of the ley is less easy to explain, why would biomass accumulation at this growth stage be lower after three years of constant soil cover, no tillage and the maintenance of a living root system within the soil?

We believe there are several factors in play. The herbal leys produce dense root systems, with a mixture of fine adventitious roots and thick deep taproots of varying C:N ratio. The contribution of N to the subsequent wheat crop is a function of the mineralisation of the N contained in these root systems following ley termination. The extent to which this occurs is dependent on the C:N ratio of the material, the weather conditions and the management applied. More intensive ploughing will cause more rapid decomposition than non-inversion tillage, and this may result in higher nutrient availability, which could explain why the more intensive tillage treatments have given higher biomass within the ley system. But this cannot be the whole story, as the more intensive treatments within the spring and winter cropping systems yielded higher still, even though the nutrient additions here were from a break crop with a more superficial root system.

This effect may have been caused by the high C:N ratio of the dense herbal ley root system. When the C:N ratio rises above 25 we expect some degree of lock-up, as the N contained in the decaying plant material is not high enough to feed the soil microbiome, and so it takes mineral N from the surrounding soil to continue decomposing. This causes low mineral N availability, which in turn can impact crop production. During crop establishment (Table 1) it was also noted that seedbed quality, through the remaining crop residues and surface crumb structure, had a significant effect on plant populations between rotational approaches. These explanations remain hypotheses, but we are continuing to investigate the impact of herbal ley cultivation and subsequent wheat production at STAR, please stay in touch with us for further information on our findings.

Table 1. Winter wheat plant populations (Spring 2022)

	Plant Population/m^2				
	Winter	Spring	Herbal Ley	Continuous Wheat	Average
Plough	208	202	186	194	197
Managed	200	193	204	222	205
Deep non-inv	197	204	191	220	203
Shallow non-inv	233	189	188	237	212
Average	210	197	192	218	
LSD (0.05)	38.2				

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Dr Robert Saville is the Innovation Growth Manager for Growing Kent & Medway, based at NIAB East Malling. He works closely with stakeholders across the GKM programme to engage businesses in the region with the facilities, resources and expertise available within the cluster.

The opportunities for alternative proteins in the UK

NIAB, through the regional investment programme Growing Kent & Medway, teamed up with UK Research & Innovation's (UKRI) Transforming Food Production team to deliver an in-depth report for the UK's alternative protein sector. *Alternative Proteins Roadmap: identifying UK priorities* (available online on www.ukri.org) identifies the key research and innovation priorities for this nascent sector, and lays out a roadmap for future investment activity.

There is a need to make the UK's food sector more resilient, efficient and sustainable. One part to help achieve this is through ensuring the potential of the UK's alternative protein sector is realised. The global market for alternative protein is set to reach $27 billion by 2027. This rise is driven largely by the consumer considerations such as interest in health, commitment to sustainability and reduction of environmental costs associated with rearing animals. NIAB and the wider Growing Kent & Medway consortium (funded by a UKRI 'Strength in Places' Award) are well placed with the expertise and facilities to support the research needs of the alternative protein supply chain. Here we discuss some of the outputs from the report and how NIAB is already addressing the needs of the alternative protein sector.

What are alternative proteins?

Alternative proteins can be produced from sources that have low environmental impact which can augment, and in some cases, replace livestock sources. The three alternative protein groups considered here are: plant-based (e.g. pulses, cereals), fermentation-based (e.g. fungi, algae, bacteria and animal cell lines) and novel protein sources (e.g. insects and seaweed).

Plant-based proteins

Plant-based proteins typically have a balanced amino acid profile, high solubility and low viscosity, which add to their nutritional value. It is mainly sourced from cereals such as rice and oats, potato and the legume family, including soy, pea, chickpea, faba bean and lentils (Figure 1). Legumes are dominating this space due to their high protein content and relatively low requirement for agrochemical inputs, in particular nitrogenous fertilisers. Some legumes (pea, faba bean, lentil) will readily form associations with nitrogen-fixing bacteria found naturally in UK soils, but others (soybean) require inoculation with specific *Rhizobium* strains. A proportion of the fixed nitrogen remains

Figure 1. Plant-based protein crops

in the soil and can be taken up by the subsequent crop, further extending the value of the legume crop across the whole rotation.

However, growing legumes in the UK can be challenging mainly due to poor yield stability and lack of varieties suited to UK climate. Breeding efforts can improve those traits, in addition to protein content, enhanced nutrition and disease resistance. The lack of diversity of species available to UK growers and the long breeding cycles required to fill this gap can be addressed in the medium term by genetic technologies, such as gene editing.

At present, the main source for plant-protein is soy, and with the UK heavily reliant on imported soy, this increases the costs and reduces the sustainability of plant-based protein products. Whilst there is some domestic UK soy production, major challenges preventing more mainstream uptake include: breeding/selecting varieties that fit better with UK planting and harvesting schedules, insufficient processing capacity, addressing regulatory constraints over genetically modified seed, and soy allergen content. This creates a great opportunity for legume crops which are already adapted to and grown in the UK such as faba bean (Figure 2).

The UK is a leading producer of faba bean in Europe. However, most of our current crop is sold for animal feed, partially substituting for soya meal in livestock and fish farming rations. Of the small proportion sold for human consumption, most is exported to North Africa with only a tiny amount used in domestic food production. Whilst manufacturers have investigated faba as a potential protein source for processed foods, substantial improvements in flavour and texture are needed through advances in both breeding and processing to fully realise this opportunity.

Faba bean is often classified as an 'orphan crop', where comparatively low levels of investment have held back improvements in genetics, breeding, agronomy, and processing. NIAB's faba improvement programme has recently been boosted by the award of a new four-year BBSRC grant, 'Enhanced Analytical and Genetics Tools for Improving UK Food Legumes (EAGLE)', led by Dr Tom Wood. This project will characterise established diverse collections for key agronomic and nutritional traits and develop advanced breeding methodologies to help sustainable improvement of the crop.

As exemplified by faba bean, there is a clear need for investment across the very fragmented plant-based protein sector in the UK:

- R&D and breeding: development of diverse protein sources; varieties with higher yields, protein content and better UK adaptation; improvement of flavour, quality, and nutritional value;
- farm portfolio expansion: crop specific machinery, knowledge base development;
- infrastructure and technological advancements: improvement of protein extraction processes, expansion of processing capabilities in the UK, establishment of production plants for legumes;
- supply chain: supply and manufacturing within a short distance (cost and environmental impact reduction), establishment of markets for co-products and waste (circularity);
- regulation: create favourable regulatory environment, including tax breaks and financial incentives.

Figure 2. Faba beans in the field

Fermentation

Fermentation-based systems for the production of protein can be separated into two main sub categories; those based on growing microorganisms (e.g. algae, bacteria and fungi) in a bioreactor and those developing cell culture technologies for cultured meat.

The first microorganism commercially grown as a protein source in a bioreactor was a fungus, *Fusarium venenatum*, and the resulting product is termed mycoprotein. Marlow Foods launched Quorn, the first mycoprotein product in the 1980s. Mycoprotein is low in fats, cholesterol, calories and has high dietary fibre. Production of mycoprotein in the UK is well established, however the demand exceeds the supply capacity.

Although not yet available in the UK, a number of companies are innovating with lab-cultured meat. This technology still needs advancements around scaling up, cost reduction, and requires regulatory change before products can be sold on UK shelves.

It has been argued that protein produced through fermentation is more sustainable than plant-based alternatives because the reduction in land and energy use needed to produce the same amount of protein leads to a lower carbon footprint and fewer greenhouse gas emissions. However, a disadvantage of fermentation-based systems is scalability and costs associated with production. This creates opportunities for:

- R&D: exploiting different microorganisms for fermentation, using agricultural waste as a substrate, expanding the final product portfolio;
- technological advances: reduced costs, robust processes, developing the technology beyond the current focus on meat alternatives to include the production of dairy and egg alternatives.

NIAB has been working collaboratively with Marlow Foods for several years now, including investigations into alternative carbon sources, increasing the nutritional profile of mycoprotein, and generating essential genetic resources for future work. Currently, we are conducting

Figure 3. Insects offer a promising prospect as a future alternative protein source

research to reduce production costs and increase biomass productivity, which will also lead to further reductions in environmental impacts of mycoprotein production.

Future investment in this area and consumer education leading to wider acceptance of fermentation-based products, particularly cultured meat, will play a vital role in the development of this alternative protein category.

Novel systems

Alternative proteins in novel systems include insects and macro algae (aquatic plants). Insects are a source of high protein, high-quality lipids, essential fats, vitamins, fibre and minerals. Currently, only a few insect species are used in these systems, namely: black soldier fly larvae, mealworms and house crickets. Current applications are in animal feed, but there is also interest in using them in food manufacturing as well.

Insects offer a promising prospect as a future alternative protein source because, in addition to their high protein and nutritional properties, they also offer the attractive circularity opportunity of using organic waste from a range of industries as a feedstock (Figure 3). NIAB's Eastern Agritech Innovation Hub, which focuses on extracting maximum value from agricultural waste products, currently hosts two firms, Agrigrub and Inspro, working with black soldier fly.

Seaweed is widely used as an ingredient for fertilisers, cosmetics and pharmaceuticals, whilst supply to the food industry is mainly limited to Asia. Macro algae biomass (Figure 4) has a high protein content and is rich in dietary fibre. The nutritional value of certain macro algae species is further enhanced by secondary products such as antimicrobials and antioxidants, which offers a great opportunity to use in food processing and as an alternative to chemical preservatives.

As per fermentation-based alternative protein, novel system protein sources face issues with scaling up, regulatory framework and consumer acceptance.

Future prospects

There are extensive opportunities in the alternative protein sector in both feed and food production with high levels of start-up activity and venture capital investment. The report recommended better coordination of the UK alternative protein community to support collaborative R&D including establishment of a UK Alternative Protein Innovation network, which would unite partners operating across the whole food value chain.

To discuss alternative protein opportunities visit www.growingkentandmedway.com/alternative-proteins/ or contact the Growing Kent & Medway team.

Alternative Proteins Roadmap: identifying UK priorities is available online at www.ukri.org.

Figure 4. Macro algae has a high protein content

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Improving soil health in vineyards

Dr Flora O'Brien is a specialist in root and soil biology in horticultural crop production, based at NIAB East Malling. Her particular areas of interest include soil health and carbon sequestration, and root-rhizosphere interactions.

Vineyards have become an increasingly common feature of the landscape across much of south east England, particularly in Kent and Sussex. The UK area under vine has risen by 70% since 2015 and, with an estimated additional two million vines planted earlier this year, this trend looks set to continue.

To the surprise of many, English vineyards are producing some of the best wines in the business, with several regularly being awarded the top accolades at prestigious global wine competitions. The majority of viticulture research to date has focused predominantly on traditional wine regions, many of which have a Mediterranean climate. There is a need for new research to provide guidance on how to sustainably manage this crop in a cool climate, given this rapid expansion of the English wine industry. A significant challenge in the UK viticulture industry is the seasonal variation in the weather, particularly late frosts and summer rainfall, which results in inconsistent yields and juice quality.

Many traditional wine growing regions have a long-held belief that the soil under a vineyard exerts a strong influence on the characteristics of the resulting wine. In France, this is encapsulated in the terroir concept, which infers that any management interventions in the vineyard that affect the soil will, in turn, affect the wine that is produced. Soil health, which can be defined as the ability of a soil to support crop production and provide wider ecosystem services, may therefore be considered as central to a vineyard's performance.

Adopting management practices that bolster soil health could enhance the resilience of vines to extreme weather events and other stressors (e.g. pests and pathogens), thereby improving the consistency and quality of the yield. Such management practices may include cover cropping and optimised methods of weed control, but currently there are no scientifically-derived guidelines to inform UK vine growers' decisions and their impacts on yield and juice quality are not known.

Commercial uptake of cover cropping in vineyards is currently limited, largely due to concerns over associated risks such as the potential increase in insect pests, higher disease pressure caused by increased humidity in the vine canopy, competition for nutrients and water, and the additional maintenance work it entails. However, research in other cropping systems has shown that cover cropping can bring significant benefits to soil health such as the alleviation of soil compaction, improved infiltration, increased soil organic matter content and, in the case of leguminous covers, increased soil fertility.

NIAB is the lead research organisation for a new Defra-funded project which aims to quantify, for the first time, the impact of cover crops and non-chemical weeding strategies on soil health, production efficiency, and juice quality in UK

The NIAB experimental vineyard at East Malling

Phacelia growing between the vines at East Malling vineyards. We are collaborating with two of the UK's leading vineyards, Gusbourne and Chapel Down, as well as a seed retailer T Denne & Sons, researchers at the Natural Resources Institute (University of Greenwich) and the vineyard and winery consultancy business Vinescapes.

The first cover crops for the project were planted in spring 2022 at NIAB's R&D vineyard at East Malling and at demonstration sites belonging to Gusbourne and Chapel Down. The cover crop treatments comprised spring oats, vetch, phacelia (all sown as straights) and a mix of all three, in addition to a control (natural vegetation). The under-vine weeding treatments are herbicide, mechanical (cultivation) and strimming for the control. Unsurprisingly, the prolonged dry weather throughout the spring and summer this year resulted in slower and less vigorous establishment of the cover crops, although the phacelia established well at all of the sites.

The research team have been busy collecting samples and taking measurements of the soil and vine, ahead of the cover crop being terminated by cultivation and new autumn covers being sown. The analysis of these samples will give an indication of the effect of these cover crops and weeding strategies on both soil health and vine performance. Various soil health-related attributes will be assessed, including soil nutrient content, hydraulic conductivity, and soil microbial biomass.

In addition to comparing different cover crop species, the project will also produce valuable insights into the management of the cover crops. At East Malling, the practice of direct drilling the cover crop seeds (as opposed to prior cultivation followed by seeding) is being tested as this is desirable to growers since it requires fewer tractor passes and causes minimal soil disturbance, thereby reducing greenhouse gas emissions from tractor fuel and soil. Direct drilling is challenging, however, as the soil conditions (compaction) and existing vegetation (and associated root mass) can inhibit germination. This was evident this year in the our R&D vineyard as the direct-drilled spring covers established poorly, although again the challenging dry conditions of the 2022 season must be taken into consideration.

The cover crop Phacelia

The cover crop Vetch

The aim of this two-year feasibility project is to provide initial guidelines for vineyard managers on optimal groundcover management, specifically on the optimal cover crop mixes to plant in vineyards with different soil types and conditions, guidance on the management of the cover crops throughout the season, and knowledge of how cover cropping and weed management affect soil health. A benefit of working with the UK wine industry compared to other wine-growing regions is that it is far less rooted in traditions and culture, and so tends to be very open to new ideas and ways of doing things. Consequently, we expect that the guidelines produced from this project will be readily adopted across the industry, and cover cropping will soon become a common feature of English vineyards.

Keith Truett • keith.truett@niab.com

Using clover as an under-companion

NIAB regional and on-farm agronomist in the south-east, Keith Truett is a former farm manager with a wide experience of different soil types, crops, large estates and small farm operations, cultivations, operational detail and organisational logistics, in various parts of the country. He is most at home as part of a team helping to contribute towards the future of the countryside and the prosperity of farmers.

NIAB first began studying the use of clover companion planting in combinable crops five years ago, following a request from a south-east NIAB TAG member. This included a preference to trial without the use of glyphosate. Looking at it practically, surely there are only advantages to having a readily available source of N, with a natural weed suppressant and added fertility – it should be a winning strategy.

In the first year of trials a medium vigour white clover was established, at 4 kg/ha, on a 50 x 50 m area within a crop of spring beans at NIAB East Malling in Kent. A low level of lucerne, at 1 kg/ha, was added to help give the companion crop greater vigour and diversity. During a dry spring both were slow to establish and by harvest the need for a top-up of clover was clear. An additional 4 kg/ha of clover was spread into the stubble, then the wheat crop was direct drilled with a Cross Slot drill. At this point I should mention the final part of the original trial request – 'do not move the soil'.

The Year 2 wheat crop of KWS Zyatt developed well and by harvest the clover was well established with an occasional lucerne plants pushing through the canopy. The surrounding commercial crop yielded ca. 8 t/ha, with the trial area at 7.5 t/ha. No effects were observed in grain quality.

Weed control had been simple, as only Clovermax (a.i. 2,4-DB + MCPA) and Pinnacle (a.i. *thifensulfuron-methyl*) plus the actives *propyzamide* and *clethodim* were the only options cleared for clover and/or lucerne and of those, the effects on wheat of some would be terminal. Trying to follow this route would prove testing.

In Year 3 the field was drilled with Mascani winter oats and, because a picture speaks a thousand words, Figure 1 shows the oats just before harvest, with the companion crop area in the background. The commercial crop harvested normally, with an average yield, but the combine driver could do nothing but lift up the header and drive over the trial as it was unharvestable due to the weed population.

The next move, in Year 4, was to return the commercial block of 60 ha of combinable cropping to winter wheat. We reverted to a standard approach to weed control on the previously reasonably weed-free site, applying a pre-emergence herbicide treatment of 0.6 l/ha of Liberator (a.i. *flufenacet* + *diflufenican*).

Within that crop the chaos caused in the companion crop block was remarkable. Brome, ryegrass and black-grass had all prospered under this joint cropping regime and a new strategy was required. A pre-harvest dose of glyphosate was applied and a further pre-drilling dose applied to remove emerged weeds before drilling winter barley and applying a full 0.6 l/ha of Liberator with Stomp Aqua (a.i. *pendimethalin*) and Avadex Factor (a.i. *triallate*). Robust and rather too much for the remaining clover plants, and I suspect the rates of glyphosate were the true control agents.

Soil health tests were then conducted on the site to review if any progress had been made. There were slight increases in worm populations with both deep living and smaller worms, which spend more time in shallow soil layers, more numerous. Greater microbial activity,

Figure 1. Mascani winter oats with the trial area behind in August 2020

using the Solvita soil health test, was also observed. No extra soil nitrogen was recovered and, at all stages, none of the crops produced more yield, leaving us to conclude the negative effects have far outweighed the positive. The barley drilled this year did appear stronger than the surrounding crop. When cut there was the suggestion of slightly more yield, 0.5 t/ha at best, but basically looking at the work with a commercial eye, I would have been disappointed and extremely out of pocket if this had been a large commercial area.

In Spring 2020 the clover work was moved to the light sandy loam of NIAB's Hinxton site in south Cambridgeshire, and also to Park Farm, a good stiff clay loam and particularly difficult for the area. Despite repeated efforts in, and out of, crop the land at Park Farm stubbornly refused to establish a reasonable stand of clover. From the lessons learnt in Kent we knew that the clover would tolerate 2 l/ha of *glyphosate* and a reasonably robust pre-emergence herbicide. But at Park Farm the clover disappeared without coming into contact with any agro-chemistry; we had to admit to being in a losing scenario.

The work at Hinxton has been far more successful. The site is far more prone to brome than other grass weeds and, as part of an environmental scheme, an area was taken out of production in spring 2021. Clover was established without any chemical intervention, as required by the scheme, with an application of 2 l/ha of *glyphosate* at the end of the scheme. We waited for more brome to germinate and then, just before direct-drilling wheat an application of a second dose of *glyphosate* was made. Knowing that spring contact herbicides would be off limits if we wanted to retain the clover a robust herbicide programme was applied for a brome site, including Avadex Factor, Liberator and Stomp. The clover paled slightly (Figure 2) then recovered in the spring and sat quite happily in the bottom of the wheat as it grew through the rest of the year. The trial was demonstrated to members and visitors at the NIAB Cambridge-Hinxton Open Day in June.

We have not yet touched on applied nitrogen fertiliser. Previous NIAB work would suggest that applying more than 150 kg N/ha would suppress the clover. However, this is exactly what the crop required so we applied 180 kg N/ha overall to enable the crop to thrive.

No additional grain quality characteristic improvements were observed in the crop and very little N can be concluded as being made available to the wheat. This work will hopefully continue and we can continue to report back any findings which growers may find helpful.

To conclude:

1. Clover needs a rotational slot in which to establish well. Spring beans were barely adequate with six months in the spring, with little competition, served the clover much better.
2. The soil health benefits of growing clover underneath combinable crops is minimal. It would be better to allow the establishment of a diverse herbal ley under one of the stewardship options for true soil health benefits, as covered in NIAB's work on the SARIC Project. Growing marginally profitable crops may well be an extremely negative thing to do under future support schemes.
3. Manage weeds carefully. Use *glyphosate* out of crop at reasonable but not full rates, 2.5-3.0 l/ha of a 360 g/litre product would be the limit, without too many additions and certainly not 2,4-D as in Kyleo, for example. Apply robust pre-emergence herbicide mixtures appropriate for the crop if in-crop options are limited.
4. Fertilise the crop as normal to achieve optimum yield.
5. The clover companion will give up most of its retained nutrients only after it has been destroyed.

On balance, there are many better ways of improving soil without compromising the rotation as a whole.

Figure 2. The clover companion crop survives the *glyphosate* management spray at the NIAB Cambridge-Hinxton site in late autumn 2021

ARTIS NIAB

Technical training courses

Classroom Courses 2022/23

23 November	**Essentials of good soil management** • Trained by Nathan Morris • NIAB Park Farm
17 January	**Best practice agronomy for cereals and oilseed rape** • Trained by Bryce Rham • NIAB HQ
2 February	**Optimising nutrient management for combinable crops** • Trained by Andrew Watson • NIAB HQ
15 February	**Using an integrated approach to weed management in arable crops** • Trained by John Cussans • NIAB HQ
23 February	**Advanced nutrient management for combinable crops** • Trained by Stuart Knight • NIAB HQ
28 February	**Gross margin, budgeting and management** • Trained by Chris Winney • NIAB HQ
9 March	**Better control and avoidance of disease in wheat** • Trained by Aoife O'Driscoll • NIAB Park Farm

Virtual Courses 2022/23

16 November	**Improving soil organic matter and farm carbon management** • Trained by Elizabeth Stockdale and Becky Willson
18 January	**Profitable growing of vegetable brassicas** • Trained by Andy Richardson
25 January	**Optimising crop management of bulb onions** • Trained by Andy Richardson
1 February	**Advanced crop management of bulb onions** • Trained by Andy Richardson
8 February	**Best practice onion storage** • Trained by Andy Richardson
14 & 15 February	**Benefits of cover crops in arable systems** • Trained by Nathan Morris
21 February	**Improving soil organic matter and farm carbon management** • Trained by Elizabeth Stockdale and Becky Willson

e-learning

Nematicide Stewardship Programme (NSP) • The NSP Protocol is now an audited part of the Red Tractor Standard for potatoes, carrots, parsnips and sugar beet. Complete the FREE online training modules to obtain your certificate and prove your compliance.

Register your interest

We are still in the process of organising some of our courses. Please visit www.artistraining.com to register your interest for a course or join our mailing list for regular updates.

01223 342495 info@artistraining.com artistraining.com

Lydia Smith • lydia.smith@niab.com

A plant ecologist by training, especially in soil-plant microbial interactions and reclamation of land to agricultural use, Dr Lydia Smith has extensive experience in the application of ecological principles to the farming environment. Lydia has a particular interest in diversification of farm species and has sought to foster interactions between academics and business, especially in the East of England. She also manages the Eastern AgriTech Innovation Hub.

Restoring soil quality through the reintroduction of leys and livestock

Soil degradation is a key threat facing UK agriculture, estimated to cost England and Wales alone between £0.9 to 1.4 billion annually. Loss of soil organic matter, increased soil compaction and erosion from continuous arable cropping and agri-chemical use is a key contributor to this. To alleviate this, attention is rapidly turning to the reintroduction of leys (temporaryrasslands lasting between one and four years) and livestock in crop rotations to restore soil quality.

In the UK, herbal leys are gaining in popularity due to their promotion in agri-environment schemes and ability to deliver greater ecosystem services than their conventional counterparts. Herbal leys, also known as multispecies leys or diverse swards, often contain a mixture of deep-rooting grasses (e.g. *Dactylis glomerata*), legumes (e.g. *Medicago sativa*) and herbs (e.g. *Cichorium intybus*) which can improve the soil structure and access subsoil water and nutrients unavailable to a conventional grass or grass-clover ley. Plants selected for the herbal ley mixture often contain high levels of plant secondary metabolites, offering a potential greenhouse gas mitigation strategy through reducing excreta nitrogen losses and improving livestock productivity. Due to their increasing popularity, these herbal leys were selected to compare against a conventional grass-clover mix for this research project.

Our multidisciplinary research team from the Universities of Sheffield, Bangor, Birmingham, Herriot Watt and institutions such as NIAB, Rothamsted Research and UK-CEH have been investigating whether a herbal ley can provide greater environmental and economic benefits than a grass-clover ley, managed either by grazing with sheep or mowing. The project, now in its final year, has split-field experimental sites on arable land in eastern England and a grassland field site in North Wales.

As the project enters its last phase, we want to develop a better understanding on how farmers perceive livestock on typically arable land, how leys are used in crop rotations, what management methods are used, and any issues that arise when leys are returned back to an arable crop.

Our key findings so far

Soil quality:

- Large taproots (e.g. from *Cichorium intybus*) improved soil structure under the herbal ley.
- Leys suffered from areas of compaction and erosion from sheep movement.

Yield:

- On heavier soils, ploughing leys rather than direct drilling achieved higher yields.
- Crops following leys required half the nitrogen fertiliser than the control.
- Weeds (e.g. *Festulolium*) from the leys were an issue in the direct drilled crops.

Animal health:

- No major impact on gastrointestinal

parasites in sheep grazing either diet.

- Herbal ley grazed lambs had a greater liveweight gain than those on the grass-clover diet.
- Higher levels of plasma selenium and plasma cobalt in herbal ley grazed lambs.

Livestock on arable land

Over the past year, a short study has been run to understand what farmers perceive to be the barriers and opportunities to having livestock (particularly sheep) on their arable land. The results of our workshops with farmers, researchers, and industry bodies (including the National Sheep Association, ADAS, and the Soil Association) uncovered four key results:

1. The extent and locations of leys in crop rotations is not well captured in Defra data.
2. It was believed that only mixed farmers adopted this method, but it is primarily large arable farmers with some grass and access to livestock.
3. Improving soil health, reducing black-grass risk, increasing drought tolerance, and improving policy support were listed as reasons for adoption.
4. Connecting livestock and arable farmers to encourage them to share equipment and expertise and information on the costs and benefits of livestock in arable rotations could encourage a wider uptake of the practice.

We also asked 70 farmers what they would need to encourage them to incorporate sheep into their arable rotations and found some farmers already doing it (Figure 1). Whilst some farmers would never consider having livestock, a quite high proportion would consider it if it was made easier or incentivised.

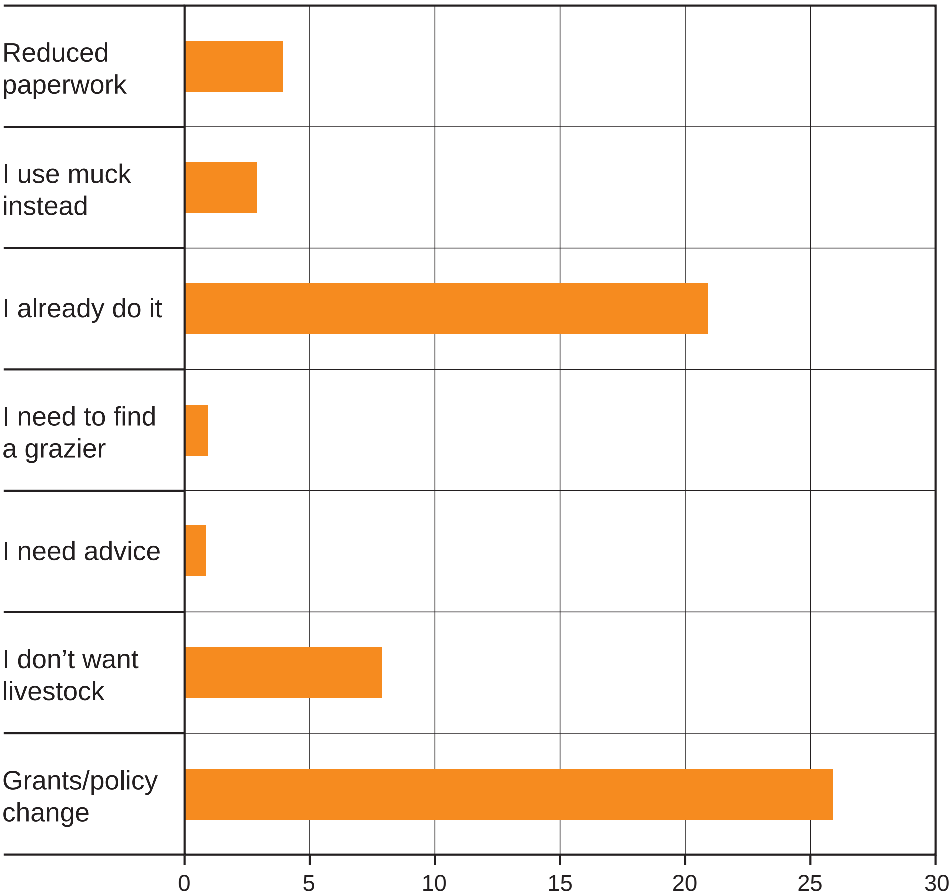
Research gaps

We have an idea of the barriers and opportunities that are facing farmers and their use of arable-ley rotations, but know little of how farmers manage their ley after the grazing has finished. This is where future research will help.

An additional online survey was made available in summer 2022, covering the farm details, ley management, how it is returned to an arable crop and any issues post-ley (e.g. weeds). The responses have helped us target areas of interest for future research and provided a highly valuable insight to policy makers on how farmers are managing their fields to help inform future policy.

For further results and information visit the project website at http://restoringsoilquality.bangor.ac.uk/.

Figure 1. Results from a survey of 70 farmers on how they could be encouraged to incorporate sheep into an arable rotation



Funding provided by the UK Biotechnology and Biological Sciences Research Council under the Sustainable Agriculture Research and Innovation Club (SARIC) programme (BB/R021716/1).

Ruth Wade, University of Leeds

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FixOurFood – transforming food systems in Yorkshire

Dr Joseph Martlew – see page 6.

Dr Ruth Wade a research fellow in regenerative farming systems at the University of Leeds. Her drive is to use knowledge and ideas from ecological systems in agricultural systems, working towards sustainable farming whilst maintaining a resilient and productive farming system. Ruth has a background in ecology and plant physiology.

The FixOurFood project, led by the University of York, is part of a series of research consortia funded by the UKRI 'Transforming UK Food Systems' programme and aims to co-create a regenerative food system across Yorkshire. The challenge of transforming our food systems to increase sustainability and resilience at a national scale is significant, so the FixOurFood project is focusing on Yorkshire as a pilot region to explore regenerative agriculture approaches that could be scaled to the UK and beyond.

The FixOurFood programme is focused on three areas:

1) sustainable and healthy food for children,
2) hybrid business models and
3) regenerative farming systems.

The University of Leeds is leading the programme of work on regenerative farming systems. Yorkshire is of sufficient size to investigate and understand the complex dynamics of farming systems, contains 13-17% of the UK's crop production area and 10-14% of the UK's livestock headcount. The variety of farming systems within the region and the diversity of soil and land cover, combined with established networks of innovative farmers, makes Yorkshire an excellent test bed for scaling regenerative agriculture.

The University of Leeds team is exploring examples of regenerative agriculture that are currently practiced in Yorkshire and beyond, to understand what can be learnt from them, investigating the environmental, social and economic factors that present a challenge to changing farming systems in the region. Working with key networks and alliances, the team will look at what practical steps are needed to stimulate shifts towards regenerative agriculture, what the regional potential is for implementation, and if regenerative agriculture could contribute to combat global warming if scaled up nationally.

In January 2022, the project team launched a survey seeking to understand the opinions, opportunities, current activities and challenges associated with regenerative agriculture. To date, they have received 166 responses, 147 (89%) said they were farmers and 79% were from England. Responses came mostly from those already practicing elements of regenerative agriculture, with the majority of participants stating the main aim of regenerative agriculture was to 'improve soil quality and fertility' and the main motivation to move towards regenerative practices was to 'improve soil health'. Most participants were using cover crops, direct drilling and aiming to reduce agrochemical inputs, and felt the biggest challenge of moving towards regenerative agriculture was the 'lack of information on good practice', 'lack of evidence' and concerns over 'reductions in yield'.

Through the survey and a series of workshops with farmers across Yorkshire, participants were asked what the University of Leeds could do to support regenerative agriculture in Yorkshire. Three key activities were identified and will be the areas the project will now focus on:

1. Spread a positive message about the work farmers are already doing;

University of Leeds researchers collecting baseline soil samples

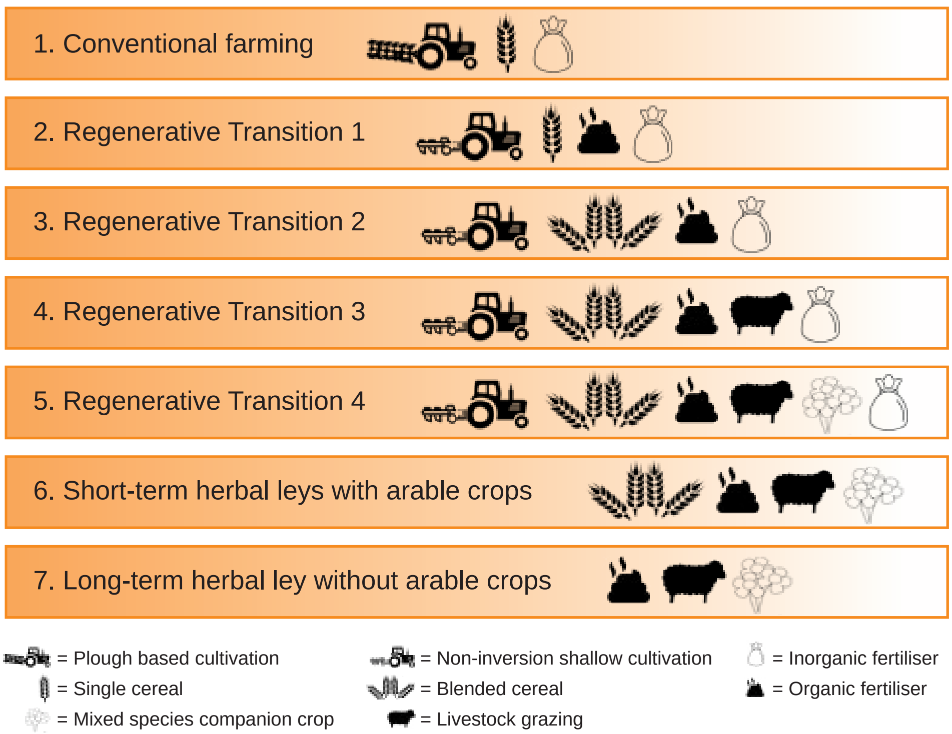
Farmyard manure application with the aim of improving soil health

2. Provide evidence-based practice guidance;
3. Support farmer-led knowledge transfer.

The main element of the 'provide evidence-based practice guidance' activity is a field-scale, replicated experiment as part of collaboration between University of Leeds and NIAB, located at its Headley Hall regional centre, based at the University of Leeds farm. The experiment, starting in Autumn 2022, will take a historically conventionally managed field and apply a combination of different transition approaches to regenerative agriculture, to measure the impact on the soil health, crop growth, agronomy, greenhouse gas emissions and economics. The seven treatments range from a continuation of a conventional farming system, through to significant changes in the rotation and the inclusion of grazing livestock, and have been designed with the input of regenerative agriculture farmers from across Yorkshire (Figure 1).

Dr Ruth Wade has recently led a team of researchers collecting information about the current physical, chemical and biological status of the soil to baseline field variation before the trial begins. Soil samples have been collected at 10 cm intervals to a maximum depth of 50 cm, and include measurements such as soil structure, soil aggregate sizes, water holding capacity, carbon and nitrogen content, and earthworms.

Figure 1. FixOurFood Regenerative Agriculture experimental treatments



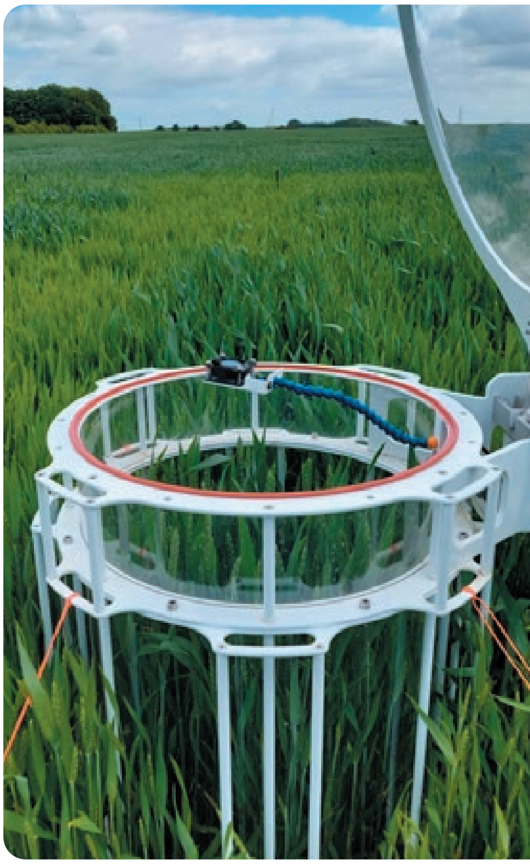
Those treatments that include applications of farmyard manure have received an application of pig manure supplied by the University of Leeds National Pig Centre at Headley Hall. Farmyard manure can be a challenge to apply to field trials due to the inconsistency of the material and the relative inaccuracy of commercial spreaders for small plots. Fortunately, The Morley Agricultural Foundation lent the project their small plot manure spreader that allowed the farmyard manure to be applied at a specific rate and only to those plots that required it. Early cultivations to those treatments that include companion crops and herbal leys have taken place to get these treatments established. This will be followed by the establishment of winter wheat single varieties and winter wheat blends in the autumn.

Throughout the trial, the project team will be measuring the impacts of the different transition approaches on soil health, crop growth, agronomy, greenhouse gas emissions and economics. The Headley Hall University of Leeds farm has been developed as a digitally connected smart-farm and terrestrial observatory. Soil sensors and automated greenhouse gas measurement chambers will be installed in the experimental plots to collect real-time high frequency measurements. The chambers automatically close and re-open throughout the day taking measurements of methane, nitrous oxide and carbon dioxide. All this information and data will be shared with the research collaborators at Cranfield University who will be modelling the impact of changing farm management practices on global warming.

In addition to collecting data, the trial will be used as a regional demonstration platform for farmers to view and discuss different management practices, and the learnings and outcomes will be fed back to the larger FixOurFood programme policy and governance team at City University. This is part of wider work by the University of Leeds to support innovative farmers and farmer groups in the region by collecting measurements and supporting on-farm trial design to test associated management practices focused on improving soil health and reducing inputs, whilst maintaining viable profits.

There are many farmers in Yorkshire exploring different management practices and we hope that this project is the start of a significant effort to support farmers in the region and the UK. For further information or to get in touch with the project, please contact Dr Ruth Wade (r.wade@leeds.ac.uk).

Establishment of the FixOurFood Regenerative Agriculture field experiment



Open gas flux chamber installed at the University of Leeds farm

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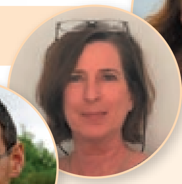

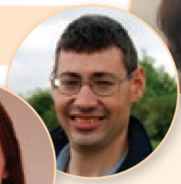

Exploiting novel wheat genotypes for regenerative agriculture

Standard farm practises such as tillage, and addition of nitrogen fertiliser aim to facilitate crop growth, reducing differences in conditions across a field, to ensure high yield. Current commercial varieties have been assessed and selected for high yield production under these standard agronomic practises. However, it is unclear how much these varieties benefit from the addition of nitrogen fertiliser, i.e. in their nitrogen responsiveness. These differences in nitrogen responsiveness may be driven by the capacity of each cultivar to take up nitrogen, which is ultimately driven by crop genetics. Selecting varieties under regenerative agriculture conditions and lower synthetic nitrogen input is likely to lead to varieties better adapted to these conditions when grown in a farmer's field.

Challenges experienced by a plant grown in a field have been traditionally addressed by physical (ploughing) or chemical modification (addition of synthetic fertiliser) of the soil environment. Here we want to explore the genetic diversity of crops that can cope with these challenges already, because they naturally carry beneficial genes, and exploit it for the selection of more resilient varieties. We will work with wheat, given its relevance to the UK and world food security. In addition, as part of its pre-breeding programme NIAB has worked for many years to increase the genetic diversity of wheat. A suite of wheat material has been created with introgressions from re-synthesised wheat (also known as synthetic hexaploid wheat or SHW) as part of the BBSRC funded *Designing Future Wheat* programme.

Early data suggest that some lines have reproducible yields that exceed the yield observed for recurrent parent, indicating that the novel introgression lines contain traits that convey a yield advantage.

In parallel, NIAB has a long history in conducting research in agronomy. In particular, the long-term New Farming System (NFS) study supported by The Morley Agricultural Foundation (TMAF) is exploring ways to reduce tillage and build fertility; these practises are components of regenerative agriculture.

In a new project funded by TMAF, NIAB will conduct multi-disciplinary research encompassing agronomy, genetics and molecular plant physiology to assess novel wheat genotypes in regenerative agriculture conditions. In agronomic research, the longevity of research projects is critical and therefore, a series of field trials will be conducted over a period of six years, starting in Autumn 2022.

Following a rotation based on winter wheat, trials will rotate across well-characterised experimental sites in East Anglia, with a known history of management. In the first year, we will assess varieties under a long-term direct drilling field at Childerley in Cambridgeshire, which was established in an eight-year study funded through the NIAB TAG membership scheme, to explore the adoption of direct drilling. The field has splits with conventional (deep non-inversion) and low-disturbance, direct-drilling approaches that can be used to overlay a fully replicated plot trial looking at fifteen novel wheat genotypes in low and high nitrogen-responsive scenarios. Additional trials will be based at the Morley regional centre in Norfolk, followed by the TMAF-supported Saxmundham experimental site in Suffolk, which was established in 1899, and include low phosphorus treatment.

Given the new policies aiming at reducing the environmental footprint of agricultural production, such as the Government's 25-year Environmental Plan and the NFU strategy for farming to reach net zero by 2040, it is important

Dr Stéphanie Swarbreck is NIAB's group leader for crop molecular physiology, studying how plants integrate and respond to different environmental conditions such as nutrient availability and the presence of neighbour, e.g. black-grass.

Dr Nathan Morris – see page 6.

Dr Sigrid Heuer is head of pre-breeding at NIAB, developing climate resilient crops, with an emphasis on high temperature stress and drought, alongside enhancing nutrient-use efficiency in crops to reduce fertiliser use.

Grace Bale is a research trials agronomist based at NIAB's Morley Regional Centre in Norfolk. She predominantly works on the long-term soils and farming systems trials, studying how environmental and genetic factors impact crop physiology and performance in the field.

to consider additional criteria besides yield. Ensuring that future wheat varieties have limited environmental impact is imperative. NIAB is in the process of developing this aspect of our research further to ensure that measurements of emission of nitrous oxide (N_2O; a potent greenhouse gas) and nitrogenous leachate are conducted on our trials.

Finally, we aim for these trials to offer a mean for collaborations. If you are interested in taking samples or measurements, do get in touch with us. We will also arrange for field visits in time – keep an eye out if interested.

THE MORLEY AGRICULTURAL FOUNDATION

NIAB is grateful for the support and funding from TMAF to support long-term funded research that enables the experiments to be undertaken across multiple seasons that is critical to gain a greater understanding of affects across sites and seasons.

Glossary

Genotype – a plant's complete set of genetic information.

Introgression – the transfer of genetic material from one line into another by repeatedly crossing with one of the parents.

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Continued progress in SWD management

Reflecting on the progress that has been made by NIAB in managing spotted wing drosophila in the UK fruit industry.

It is 12 years since spotted wing drosophila (SWD) (Figure 1) was first recorded in the UK at NIAB's East Malling site in Kent, but the work to manage and control this invasive pest had already begun before its arrival. Scientists and technical managers had mapped its movement from its origins in Japan to the USA, then mainland Europe. By 2011, the UK fruit industry had formed an SWD Working Group to consider how to manage it when it gained entry here. Since 2012, NIAB entomologists have led the lion's share of UK funded research into the pest, but why was it so important to the industry to learn how to manage and control it?

SWD (*Drosophila suzukii*) is a fruit fly, but unlike the common fruit fly found in the UK (*Drosophila melanogaster*) which is only attracted to overripe fruits, SWD is attracted to fruit of all ages. Females have a saw-like ovipositor which makes an incision in the surface of developing soft skinned fruits. Eggs are laid under the surface of the skin and hatch into larvae, which not only contaminate harvested fruits, but feed on the flesh, causing the fruit to collapse, rendering it unmarketable. Cherries, blueberries, strawberries, raspberries and blackberries are particularly susceptible to damage. If left uncontrolled, 100% crop loss can occur in cherry and over 50% in other susceptible crops.

Research progress

AHDB spent more than £1.6 million over ten years, funding research projects with NIAB and other collaborators , with additional funds provided by Defra, British Summer Fruits, Innovate UK and The Worshipful company of Fruiterers. Here, we summarise NIAB's research that has aided industry in the fight against SWD.

The first AHDB project (SF 145) focused on four key areas of research including:
1) monitoring for the pest; 2) habitats and pest dynamics; 3) crop management and hygiene; and 4) control.

The project tested different traps and monitoring devices and a range of attractant lures which helped growers to choose practical monitoring options for their own farms (Figure 2). Work was also carried out to help growers to identify the presence of larvae in developing fruits using flotation methods (Figure 3).

Figure 1. Adult male SWD with characteristic spots on its wings. Females have no spots

Figure 2. Biobest Drosotrap typically used by many growers to monitor for the presence of adults

Dr Michelle Fountain is NIAB's Head of Pest and Pathogen Ecology at East Malling, specialising in the minimisation of pesticide use in fruit horticulture, improving pollination in fruit crops and incorporating modern fruit growing practices with Integrated Pest Management.

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.

We learned a huge amount about how, and where, SWD adults live and overwinter and when they start to migrate into soft and stone fruit plantations. This has helped growers to know when, and where, to monitor for SWD adults and larvae.

We recognised how vital it is to remove old, damaged and diseased fruits from plantations (Figure 4) and then investigated how to dispose of waste fruit through fermentation (Figure 5) and incorporating this fermented waste into field soils.

Finally, we experimented with agrochemical control agents to assess their relative ability to control SWD adults in UK conditions. NIAB identified that synthetic pyrethroid products work well, but these are incompatible with IPDM programmes used for other pest and disease problems. The spinosyn product Tracer is extremely effective as are the cyantraniliprole products Exirel and Benevia.

The grower guidance arising from

Project SF 145 was summarised in AHDB Factsheet 06/17 (*Management and control of spotted wing drosophila*).

Further AHDB-funded projects have allowed NIAB to investigate three particularly exciting new control approaches including the reduction of over-wintering populations, the use of a 'push-pull' technique and the use of bait sprays for control during the season.

In research at NIAB's East Malling site, where grids of precision monitoring traps were deployed in native woodlands (Figure 6) adjacent to soft fruit crops (Figure 7), fewer SWD adults emerged from the woodlands in spring. Preliminary data is also showing that the traps nearest the crop on the woodland edge captured the most SWD, enabling growers to make better decisions about trap placement. Although numbers of SWD increased in the crop later in the year, a reduced population of the pest emerging in spring will help growers to manage the pest more effectively early in the season.

The aim of the push-pull management approach was to combine the use of repellents and attractants, so that the pest could be pushed away from the crop using a repellent and attracted into a trap containing a fatal component. Work done by a Collaborative Training Partnership for Fruit Crop Research (CTP-FCR) PhD student at NIAB (with the Natural Resources Institute at Greenwich), identified three compounds that repelled SWD and in experimental polytunnels, two of these significantly reduced egg laying at distances over 6 metres. However, these results could not be reproduced when tested in commercial cherry and raspberry crops, so further work is required.

The NIAB bait spray research, in collaboration with Microbiotech, has been very successful in strawberry, raspberry and cherry. Molasses and a commercially available adjuvant Combi-Protec are both very attractive to SWD adults. When added to Benevia on strawberry or Tracer and Exirel on raspberry and cherry, and sprayed to a reduced area of the crop canopy, they attracted SWD adults to feed on the sprayed leaves, allowing them to ingest the control chemical causing death. When using most adjuvants, plant protection products must not exceed 50% of the normal recommended rate. We experimented with 50% of the recommended rate and lower, and when applied as a band of large droplets (Figure 8), achieved comparable control to full rate sprays.

The bait spray work has identified an effective alternative to using full foliar applications of the full rate of product by applying to a reduced area of crop canopy. This offers the chance to reduce the risk of chemical residues, whilst also decreasing the total cost of application, both in terms of the quantity of product used and the time taken to apply the spray to a small area of the crop canopy. This strategy

Figure 3. Flotation testing for larvae in fruit

Figure 4. Waste plums on orchard floor

Figure 5. Waste fruit being held in anaerobic conditions

Figure 6. Precision monitoring Sentinel Fruit Trap in woodland

also helps to protect other biocontrol agents released into or entering the crop. Further work continues to develop an authorisation for the use of molasses as an adjuvant, so that it can be used by commercial growers. It should be noted that Combi-Protec is already authorised for use in the UK as an adjuvant (applied with 50% rate of product) but only in combination with products with standard 'on-label' or EAMU authorisations and not emergency authorisations. The manufacturers of Tracer, Exirel and Benevia have not yet funded their own work on bait sprays, so do not currently support this method of application.

Figure 7. Precision monitoring crop-woodland adjacent to soft fruit crop

Additional research

The Worshipful Company of Fruiterers has funded two additional projects at NIAB looking at novel integrated approaches to control. The first, in partnership with Berry Gardens involved entomologists at NIAB identifying parasitoids emerging from SWD larvae and pupae. Five native species were identified, but unfortunately the pupal parasitoid *Trichopria drosophilae* was not among them. This latter species is commercially available in mainland Europe for use in biological control, but as it has not yet been identified in the UK, it cannot be released in UK crops.

A further study funded by The Worshipful Company of Fruiterers at NIAB involved the use of biotremology, the study of mechanical vibrations and their effect on organism behaviour. Some insects such as the European tarnished plant bug are known to use vibration signalling at species-specific frequencies during courtship. It was thought that by creating vibrations through the crop canopy, we could disrupt mating and reproduction of SWD. A method for applying biotremology to the crop was developed in the laboratory and this worked successfully through the tabletop strawberry truss support tapes in the field, but neither SWD feeding or egg laying was deterred. Further work needs funding to investigate the vibration emission method and its transmission through the crop.

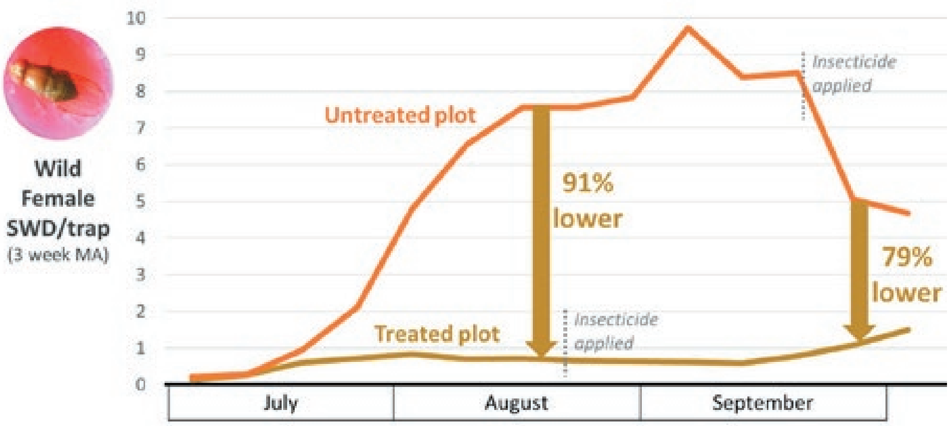
In addition, a current NIAB-led BBSRC-IPA project, in collaboration with researchers at the Natural Resources Institute and Berry Gardens, is investigating the life stages and chemical signals produced by other Drosophila species that deter SWD from laying eggs. This study is under review for publication and will be reported in the near future.

An exciting new development

One light at the end of the tunnel giving growers hope is the Sterile Insect Technique (SIT) being developed by BigSis in collaboration with NIAB at East Malling and funded by Innovate UK and Berry Gardens. Sterile males are introduced regularly to the crop to mate with wild female SWD, which fail to produce any offspring. Early trials on strawberry in open polytunnels have shown encouraging results with SWD levels remaining very low throughout the season compared to plantations treated with agrochemical products, where populations show peaks and troughs due to the latter mostly being effective only on the adult flies (Figure 9). More detail can be found at https://pubmed.ncbi.nlm.nih.gov/35447770/. This research has continued through the 2022 season, and BigSis plans to offer this technique as a commercial service to fruit growers, starting in 2023.

Figure 8. Bait spray applied as a band of large droplets

Figure 9. BigSis_2021 Trial showing how the SIT techniques maintain low populations of SWD compared to the use of crop protection sprays



Elizabeth Stockdale • elizabeth.stockdale@niab.com

Working to support farming resilience

Dr Elizabeth Stockdale – see page 4

The challenges caused by food supply chain pressures, rising input costs, extreme weather events and the changes to agricultural support will require many farmers in England to adapt their business models and carefully consider options for the future.

Support payments to farmers

The EU Common Agricultural Policy (CAP) provided the framework for farm payments in the UK until Brexit. Direct payments were made to farmers who met basic rules covering food safety, public, animal and plant health, climate change, environment and landscape. Part of the original rationale for these payments was to recognise the benefits to the landscape and environment provided by farmers but that were not recognised within the agri-food market. On average over the period 2014-2017, direct payments made up 9% of revenue across all farm types. The proportion of revenue from direct payments was highest on average in grazed livestock systems. Direct payments to arable farms (cereals) made up 15% of revenue on average, equivalent to 79% of average farm business income. Farmers were also able to access additional payments for actions taken to look after and improve the environment, known as Countryside Stewardship, e.g. conserving and restoring wildlife habitats, flood risk management, woodland creation.

After Brexit – what next?

The direct payments to farmers (Basic Payment Scheme, BPS) are now being phased out. From 2021, a seven-year transition away from EU-based rules began in English farming. Different rules and schemes are in place for Wales and Scotland, as agriculture is a devolved issue. As a result, farming in England is going through the biggest change in a generation. Defra's stated aim is to develop policies that work for farm businesses, food production and the environment and that enable farming and food production to be resilient and sustainable over the long term, where farming and nature can go hand in hand. There will be one-off grants available to help farmers invest in technology, equipment, and innovation. But new on-going funding to farmers will largely be contingent on the delivery of environmental outcomes through the Sustainable Farming Incentive. The best way of staying in touch with the latest updates and information from Defra is by subscribing to the Future Farming blog (search for 'Defra Future Farming blog' online).

Reductions in direct payments will occur more quickly for those in receipt of the largest payments and hence, given the relatively large land areas associated with arable farms, this sector will be affected quickly during the Transition. Many farmers are already looking for ways to reduce costs, improve farm efficiency and diversify (where possible). Research studies, e.g. those carried out by the RBR (Rural Business Research) and also by Andersons for AHDB, show direct benefits of increasing agricultural managerial skills for business performance (financial, technical, well-being) and environmental delivery. Where farmers take an active role in developing their own structured approach to change management, research confirms that approach is highly likely to improve farming businesses and enable on-farm delivery of wider Defra objectives.

All farmers are looking for support to consider a range of new options robustly and enable them to adapt their farming systems, crop and livestock management and business structures to address the new opportunities and challenges. Hence there is a need for farmers to acquire and integrate information across a range of topics including soils, water, crop management, markets and logistics and to take both a wider (financial, technical, wellbeing) and longer-term focus to their business development. Therefore Defra have committed £32 million to provide advice and support to farmers as they move forward through the agricultural transition through the roll-out of the Future Farming Resilience Fund which will begin in October 2022.

The Fund will be supported by 17 advice providers delivering information, tools, advice, and support for farming businesses across England throughout this period of change. As part of this programme, NIAB, management consultants Savills and financial consultants AKC are collaborating in a new programme of support and advice for arable, mixed, dairy, beef and sheep farming businesses throughout lowland England.

A key part of farm business resilience is the personal resilience of the farmer and so we will continue to work with the Farming Community Network www.fcn.org.uk to ensure that we can also provide simple and accessible resources to support well-being and direct farmers to further support. This collaborative approach will provide scope for the most effective delivery to arable, mixed, dairy and beef and sheep farming businesses throughout lowland England, allow farmers access to online tools, resources and industry expertise through a network of 30+ experienced farm business consultants.

For more information go to www.niab.com/future-farming-resilience-fund

What we have learned so far – working with farmers on farming resilience

In the winter of 2021, NIAB delivered a Future Farming Resilience Fund pilot project with farmers in the Cotswolds and Wessex areas. We worked with 75 farmers through a series of workshops and on-farm visits covering the impacts of changes to direct payments, exploring options for farming system change and developing change management skills. In this project, NIAB aimed to provide each farmer with a toolkit to plan, implement then monitor changes at small-scale before acting to roll-out change across the business. Although not necessarily easy, one of the participants said, "I found NIAB's approach rewarding and challenging at the same time; the NIAB team supported me to reflect on my own business strengths and weaknesses, and then worked with me to help me move forward". At the same time Savills and AKC worked in partnership with AHDB to deliver strategic advice, business planning and performance monitoring to help farm businesses explore their options and benchmark performance.

Some of the key issues for farms that have emerged from the Farm Business Reviews carried out in the pilot phase are:

- Agribusiness challenges are business specific, but key areas of focus are;
  - enterprise and system change including diversification planning,
  - setting financial goals / managing risk and budgeting,
  - business structure change including succession, retirement planning and contract farming.
- Many farms are looking to improve efficiency and manage overheads to address BPS loss. Benchmarking the full economic cost of production and enterprise gross and net margins allow quick comparisons to top and average performers so that weaknesses can be pinpointed, but these data can be difficult to find or to make sense of.
- In the arable sector there is an appetite on farm to explore a range of integrated system changes to reduce input costs and improve environmental impact through farming system change towards regenerative approaches. However, farmers were looking for support to understand the options from a technical perspective and implement technical baselining (e.g. soil health, yield map analysis).
- Interest in new environmental land management approaches, farming in an environmentally sustainable manner, carbon audits and relevant funding sources is high. This ranges from exploring existing countryside stewardship and the new SFI options, viability of renewable energy, tree planting; to looking at the farm infrastructure required to manage and store manures better or reduce ammonia emissions from livestock housing or a resource efficiency evaluation looking at electricity and water usage.
- Workforce and people planning – labour shortages and availability of skilled labour is an issue, especially on dairy farms and in horticulture. Farm businesses are looking for support to aid recruitment and retention of staff.
- A particular focus was the potential value of an annual review of the business more widely focused than an accounts-only conversation. Many businesses were already recording a range of information, from staff and external advisors, but most felt that they could use it better.

Overall, the work to date has confirmed that the future funding schemes are not going to be a direct replacement for BPS. The impacts of the loss of the BPS payments are simple to calculate but options to mitigate revenue loss will be individual to farm businesses. Therefore, a profitable future is going to be about developing a farming system that works best for that location and using all the tools at a farm's disposal, where environmental payments will be just one of those tools.

www.niab.com/future-farming-resilience-fund

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ForaGIN – improving forage crops to increase farm productivity

The value of drought resistant leys and forage species to ruminant livestock systems has become increasingly apparent with another year of feeding winter forage stocks in the summer months. Recent NIAB project work has identified some of the currently underused species with the most potential to support more resilient productivity, whilst reducing reliance on expensive inputs and increasing biodiversity, protecting natural resources and capturing carbon.

ForaGIN is a Defra-funded scoping study project, led by NIAB and SRUC, assessing the opportunities and barriers for forage crops in the UK. The aim was to scope opportunities for the potential of improved forages to improve farm productivity, environmental sustainability and resilience to climate change to account for the future needs of ruminant agriculture in the UK. Information was gathered using online farmer questionnaires and face-to-face stakeholder workshops.

The survey helped identify grower interest in a range of forage crops including diverse swards, legumes and herbs. It also raised a range of challenges to forage production with changing weather patterns identified as the main concern alongside significant challenges with weed control in legumes and mixed swards, matching crops/varieties to the soil type and climate, establishment of some legumes and establishing legumes/herbs within existing swards.

These forage crops were scored against productivity, resilience and environment criteria with reference to their potential compared to a baseline of perennial ryegrass swards against a range of characteristics outlined in Table 1. These were then analysed against a range of challenges such as increasing resilience to changing weather patterns, reducing GHG emissions, mixed/companion cropping and opportunities of stewardship mixes as well as which traits and species are important for a robust future forage system.

A final shortlist of crops was compiled (Table 2) by considering overall and average scores for productivity, resilience and environment characteristics and the number of characteristics where high scores (>4) were achieved compared with current forage systems (which are considered to achieve score 3).

Limited data are available on forage crop productivity and quality on many underused crops with direct relevance to UK conditions. Agronomic research data is species specific (monocultures), whereas in practice many forage crops are grown in crop and/or variety mixtures. The shortlist aims to create a focus for research and development activity over the next five to ten years. Crops not currently shortlisted may also become important forage options for UK systems.

Focus on breeding

On-going research and development in pre-breeding will continue to improve nutritional value, environmental tolerances, disease resistances, persistence, and agronomic performance of forage species. For red clover, stakeholders highlighted the opportunities arising from novel genetics for increased grazing tolerance as well as greater persistence, as monocultures and in mixed swards. These traits would markedly increase the opportunities to integrate red clover within a wider range of forage systems.

Opportunities arising from high throughput phenotyping approaches, together with genomic selection approaches, may allow more rapid progress in breeding of forage crops in the future.

As new forage species and varieties become available, variation in performance between varieties should be independently assessed in descriptive

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.

Table 1. Crop characteristics used to compare forage species

Productivity	Improved yield
	Improved digestibility
	Improved protein content
	Increased micronutrients/health benefits
	Reduced anti-nutritional factors
	Reduction in enteric methane
Resilience	More drought tolerant
	More waterlogging tolerant
	Less susceptible to pest and diseases
	Higher reliability of forage supply
	Increased reliability for conservation (storage)
Environment	Reduced N fertiliser
	Improved biodiversity
	Rapid ground cover – reduced erosion risk
	Increase soil carbon content
	Improved soil structure

or recommended list trials programmes, although whilst varieties are few in number, the cost of such programmes are prohibitive to breeders unless there is sufficient market demand for this information, or it is supported by the public sector. This is particularly the current situation with fodder beet. Where such variety evaluation programmes already exist, it is appropriate to review characteristics relating to resilience and environmental sustainability are identified and considered as part of variety assessment and selection.

Focus on legumes

There is a need to increase understanding of legume N fixation rates and livestock utilisation efficiencies in UK conditions. Increased understanding of bloat risk and mitigation is also needed, together with more information on the action of condensed tannins for NUE/ protein digestion when they are fed as part of forage mixtures. The interactions of mixed forage species within the rumen and throughout the digestive tract is needed in order to understand optimise protein digestion, methane emissions, anthelmintic effects and other health benefits. Prioritisation of integrated research (detailed crop and livestock science, applied research and knowledge exchange) to address knowledge gaps for herbal leys, sainfoin, red-clover and lucerne was considered most likely to increase the rate of uptake of underused forages to increase livestock sustainability and productivity. The loss of clover-safe herbicides may increasingly constrain the adoption of forage legumes in practise.

Focus on species mixtures

Integrating both basic and applied research along with robust knowledge exchange, is critical to address the species interaction effects during growth and utilisation, particularly on nitrogen use efficiency, as these are relatively weakly understood and difficult to manage in practice. Addressing knowledge gaps on herbal leys, sainfoin, red-clover and lucerne was identified as a priority by stakeholders with research (both basic and applied) needed on forage crops as components of mixtures. More evidence is needed on productivity, resilience and environmental impact of herbs within mixed swards. Meeting livestock needs throughout the growing season whilst accommodating annual variation in composition within a mixed sward will require careful monitoring and management.

The final report is available on the Defra Science website at https://bit.ly/3Csp9gh

Table 2. Final shortlist of forage crops comparing productivity, resilience and environmental characteristics. Each crop was scored as better (4,5) or worse (1,2) against a base level of perennial ryegrass swards (3)

	Overall average	Average productivity	Average resilience	Average environment	No of scores >4
Reference crops					
Ryegrass – perennial	3.64	3.73	3.77	3.48	0
White clover	3.35	3.68	2.98	3.45	5
Shortlisted species					
Ribwort plantain	3.50	3.46	3.45	3.58	2
Sainfoin	3.45	3.60	3.02	3.72	4
Lucerne	3.44	3.72	3.21	3.46	4
Annual cloversn	3.42	3.58	3.11	3.56	3
Chicory	3.38	3.54	3.20	3.43	2
Birdsfoot trefoil	3.38	3.50	3.08	3.54	3
Festulolium	3.37	3.08	3.65	3.32	1
Red clover	3.29	3.64	2.90	3.39	3
Other perennial clovers	3.36	3.53	3.13	3.45	1
Vetch (tares)	3.26	3.42	3.01	3.36	1
Forage lupins	3.19	3.35	2.80	3.40	2
Fodder beet	3.00	3.49	3.09	2.59	2
Forage trees	3.33	2.87	3.47	3.52	6
Multi-species/herbal leys					
Yarrow	3.19	3.04	2.97	3.46	3
Sheep's parsley	2.98	3.05	2.65	3.21	2
Burnet	2.97	2.71	2.83	3.26	2
Greater birdsfoot trefoil	3.41	3.49	3.15	3.56	2

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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 – this month it is **Aceae Nutra** and **PES Technologies**.

BARN4 AGRITECH INCUBATOR

Through initiatives such as Barn4, the Eastern Agri-Tech Innovation Hub, Growing Kent & Medway and Cambridge AgriTech, 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.

Developing plant-based anti-virals

ACEAE NUTRA

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

Aceae Nutra is an IP focused biotech SME. Founded in 2018 to develop novel animal and human antivirals, Aceae compounds are sourced from an edible crop species. Our approach incorporates a pharmaceutical style discovery and development programme, alongside plant sciences expertise. Collectively we generate viable plant-based solutions with proven efficacy and tractable manufacture. Our technology is suitable for use at scale in the volume-driven livestock sector.

Partnering with industry and leading academic researchers, the Aceae team has identified and developed novel bioactive antivirals to control the spread of key agronomic and pandemic class viruses. The team incorporates experts in virology, plant breeding, molecular sciences, and feed processing. Our technology includes compounds discovered and patented from a non-GM fruit with a low-cost manufacturing

Figure 1. Aceae Nutra use NIAB's glasshouse facilities to grow new plant material

profile. Supporting data comprises of a portfolio of in-silico and in-vitro experiments, testing for effects including anti-infectivity, reducing the severity of infection, and limiting viral pathogenesis. Aceae compounds show exciting broad antiviral activity against key agricultural viruses.

With a core focus on discovery and early development, our pipeline is simple and scalable with manageable risk. We develop our technologies together with leading industry/academic partners e.g. global brand animal feeds corporates and opinion leading translational scientists with clinical expertise.

How does your product/service benefit the agriculture or wider industry?

Viral pathogens cause billions of dollars of agronomic damage each year. Many different sectors are impacted, with few effective treatments currently available. Industries particularly affected by seasonal viral infection including pigs, cattle and sheep, aquaculture e.g., salmon and shrimp. Secondary considerations include costs incurred through loss of biomass to pathogens, both economic and environmental e.g., carbon/energy expended in (wasted) feed manufacture. Aceae is looking to develop solutions that reduce losses in agriculture (profitability), to sustain animal health, welfare and improve food security.

A good example is the 2001 UK foot-and-mouth outbreak. One simple RNA enteroviruses resulted in the loss of over six million cows and sheep, in an attempt to limit the disease. The crisis cost the UK over £8 billion financially, with additional high societal costs.

Why did you join Barn4? How has it helped to develop and support your start-up?

Aceae Nutra joined Barn4 in November 2021. For us it is an ideal location with great facilities, giving access to a wealth of scientific expertise and access to one of the world-leading centres for agritech research. We were awarded grant funding by Innovate EDGE support to grow new plant material, via Barn4 using NIAB's glasshouse facilities (Figure 1). NIAB also provides research-grade disease-free growing capability, allowing the cultivation, and crossing of key lines from the germplasm collection. Working together with NIAB, we also undertook pilot trial scale optimisation of growing conditions. This R&D programme helped expand the Aceae Nutra IP estate, adding value to our business and providing assurance to future partners that Aceae Nutra technology is sufficiently protected. NIAB-based research enabled further product development with a clear route to market.

Aceae Nutra
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Sniffing out good soil health

PES TECHNOLOGIES

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

Organisms in the soil release a range of volatile organic compounds (VOCs) as part of their metabolic processes. Collecting these volatiles by sniffing the soil and then analysing their composition provides a rapid way of measuring the biological community in action. PES Technologies has developed a handheld soil 'aroma scanner' and machine-learning database to provide in-field results to agronomists and farmers mobile phones within five minutes. Initial work has shown that the measured responses can be correlated with soil biological activity. The sensor is currently being trained to see how well it detects a wider range of soil health characteristics (including microbial biomass, soil organic carbon (%), available NPK and pH), and all results are time-stamped and GPS-logged. We will be conducting trials this autumn with our alpha prototype, and intend to launch commercially in the UK in early 2024.

How does your product/service benefit the agriculture or wider industry?

Understanding soil health is key to optimising crop yield whilst reducing inputs, but a lack of rapidly deployable, affordable testing is stopping farms from measuring soil health and implementing soil-improving actions on-farm.
We have worked with industry and academia through Innovate UK-funded projects to develop a test that can provide comprehensive data about soil biological activity and health and help optimise business-led decisions about soil. Additionally, we want to facilitate mass-testing, so that businesses can do as many tests as they need to really understand soil health and its impact in monetary terms.

We also know that the understanding of soil health will evolve as we all learn more about it. PES is able to train our product on new machine-learning datasets as this understanding grows, allowing us to provide new characteristics within a year.

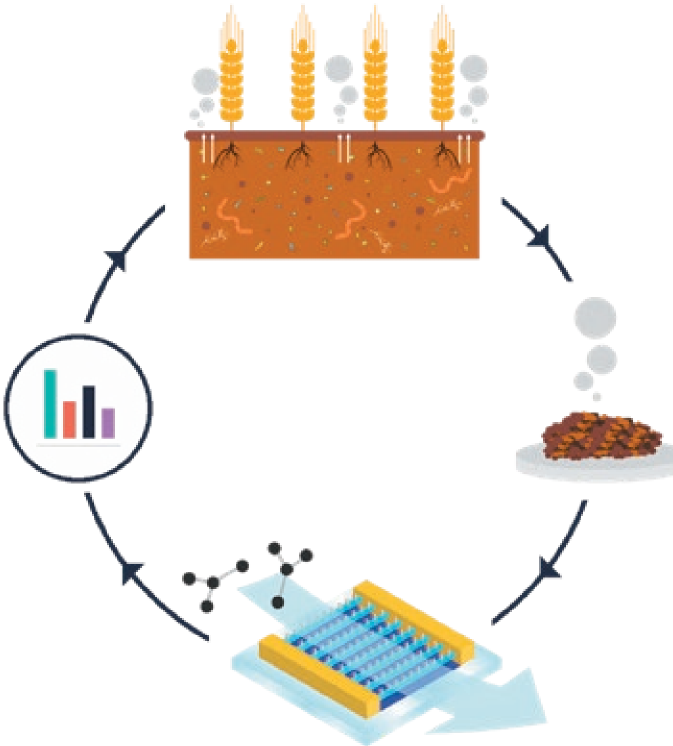
Our product will initially focus on soil health for arable farmland, but we intend to train it for grassland systems as well as to help farmers build carbon stocks and store carbon in the soil.

How are you working with or supported by NIAB?

Working with NIAB has been absolutely instrumental for us. We conducted an IUK-funded proof-of-concept project with NIAB's Dr Charles Whitfield and Dr Emma Tilston to see whether gas 'fingerprints' from microbial activities in soil samples (detected by our sensor) could be linked to biological indicators of soil health. We found we had strong correlations with many of them, including microbial biomass, soil organic carbon (%) and respiration.

As a result, we set up a follow-on project involving NIAB, Hutchinsons, The Small Robot Company, the University of Essex and the University of Greenwich to develop our sensor tool from a lab-bench prototype to near-commercialisation. This project is wrapping up in November this year, and although affected by COVID, we have made excellent progress towards commercialisation in early 2024. We were very grateful to present the project as part of NIAB's stand at the 2022 Cereals Event.

We always welcome the chance to work with experts on NIAB to expand the possibilities of our sensor product; if you have ideas on an area of agriculture you think our tool could be useful in, we would be keen to discuss how we can get a project off the ground!



Monitoring soil changes over time

The sensor allows frequent measurements to be taken during each year. Trends in the data over time are used to inform changes to land management practices and monitor the results of amendments. The sensor can be used as a handheld device, or integrated onto a robot for automated field assessments.

The handheld soil scanner provides in-field results to mobile phones

Why did you join Barn4? How has it helped to develop and support your start-up?

Being part of Barn4 has helped us meet experts from NIAB who have suggested potential future uses for the product. It has also given us access to meeting facilities such as the Sophi Taylor Building at NIAB Park Farm – being an SME, it is good we can use an impressive venue when hosting shareholder or customer events.

At a technical level, Barn4 offers a rather unusual facility we found we needed – namely, an open-air laboratory. While our 'lab' was predominantly meant as a garage for storing robots, it provided the perfect conditions for our team to test prototypes and analyse soil samples in near-real world conditions – the fresh air that circulates through the garage was ideal for simulating being outdoors whilst protecting our equipment (and ourselves!) from the elements.

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Growers take the lead in NIAB's Plum Demonstration Centre

NIAB's horticultural research at East Malling has delivered many benefits for commercial growers down the years, but the adoption of new practices and technology on-farm does not always keep pace with our scientific outputs. One way of speeding up this process is to demonstrate the findings in a commercially-relevant setting, and the site at East Malling now has three 'Demonstration Centres' to fulfil this purpose.

Dr Mark Else is Head of Crop Science and Production Systems at NIAB East Malling, whose research focuses on understanding and manipulating crop and environmental interactions to deliver improved resource use efficiency, crop productivity and quality of fresh produce.

Scott Raffle – see page 23.

The most recently opened is the Plum Demonstration Centre (PDC). Tree planting began in the orchard in 2016 as partial fulfilment of an Innovate UK (IUK) project that NIAB participated in between 2015 and 2019. The project focused on enhancing yields, reliability of cropping, extending the production season from July to October, and improving fruit value by raising the quality of the fruit being marketed and consumed. The PDC has evolved over the ensuing years to meet a number of objectives.

Rootstock

The performance of the cultivar Victoria has been compared on four rootstocks (four replicated 5-tree plots) of varying vigour including VVA1, Wageningen, Wavit, and St. Julian A. The planting allows replicated comparisons of the performance of Victoria including tree size/vigour, flowering time, ripening time/season, disease susceptibility, productivity, and fruit size and quality.

The different training system/rootstock combinations include Narrow table-top, Narrow A frame, Oblique spindle and Super spindle systems on the rootstocks VVA1, Pixy, Wavit and St. Julian A (Figure 1). Two single rows of Victoria have also been compared on Fan and Candelabra systems.

To date, the Oblique, Super spindle and Narrow A frame systems on VVA1 and Wavit rootstocks have produced the highest yields, although a high percentage of VVA1 rootstocks have died. More years of production are required before firm conclusions can be drawn on the optimum combinations.

Yield and quality

Between 2019 and 2022, the PDC at East Malling was funded by the Agriculture and Horticulture Development Board (AHDB), when it evolved and expanded to incorporate a comparison of yield and quality from tunnel-covered areas of plums with uncovered, a demonstration of mechanical weed control, and the implementation of results from AHDB and other funded tree fruit research projects.

This included research projects on the preservation of earwigs in orchards and conservation biocontrol (Figure 2). The PDC now follows 'earwig-safe' spray programmes, deploys earwig refuges, uses wildflower strips around the Centre and between crop rows (in certain areas), and the use of beetle banks. The numbers of earwigs and pollinators are being assessed and recorded, with comparisons of earthworm numbers also being made between bare soils, grass strips and wildflower areas.

Figure 1. Oblique spindle training

Variety trial

In 2020, 23 new selections and varieties were planted in a dedicated variety trial plot to gather yield and quality data from a range of varieties that will extend the season from the start of July until the end of September. This includes varieties in Table 1 which are compared to Victoria as the standard.

Following the IUK-funded project, three other trial orchards were planted by commercial growers in Kent to showcase different plum varieties; AC Hulme & Sons (early varieties), Highwood Pluckley Ltd (late varieties) and GH Dean (varieties with high yield and quality potential). All three growers share their experiences and findings with the industry, including through NIAB events and publications.

New beginnings in 2022

Following the winding down of horticultural activities at AHDB in 2022, new funding for the Plum Demonstration Centre was successfully sought from the industry, and a new consortium was developed to fund the maintenance of the Centre and steer the activities which are considered most beneficial to UK plum growers (Figure 3). The Consortium consists of 11 plum growing businesses and three marketing groups, who have taken a 'hands-on' approach to the management of the Centre, providing help and support with some of the husbandry tasks undertaken there.

The Consortium members want to improve their knowledge and understanding of precision irrigation and fertigation in plums and optimise nitrogen inputs, topics which are becoming increasingly important as the availability of water becomes ever more scarce and the cost of fertiliser products continues to increase.

This year NIAB installed soil matric potential sensors at a depth of 15 cm, 30 cm and 45 cm and a volumetric moisture content sensor at 45 cm under representative trees. Irrigation (and fertigation) was initially triggered at an average soil matric potential value of -60 KPa across the rooting zone. This irrigation threshold was then lowered throughout the season to a value of -100 KPa. Prior to harvest, some trees were allowed to dry down to below -400 kPa and then returned to field capacity to try to simulate the effects of a heavy rain event on fruit splitting before harvest. This work will help us to better understand the demand for water by plums at different stages during crop development and to identify the optimum soil moisture deficit at which to irrigate – work that has already been done at East Malling on other tree fruit crops.

The Centre's team has compared water availability in trees managed with mown grass alleys versus those with

Figure 2. Monitoring insect pests in NIAB's Plum Demonstration Centre

Table 1. Varieties in trial at the NIAB East Malling Plum Demonstration Centre

Variety	Cropping season
Herman	Early July
Katinka	Mid July
P7-38	Mid July
Juna	Mid July
Meritare	Late July
P6-19	Late July
Opal	Early August
Lancelot	Mid August
Avalon	Mid August
Julieum (Jubilee)	Mid August
Ferbleue	Late August
Top Five	Late August
Victoria	Late August
Haroma	Early September
Seneca	Early September
Marjory	Early September
Top Taste	Mid September
Coe's Golden Drop	Mid September
Laxton's Delicious	Mid September
Top Hit	Mid September
Haganta	Late September
Top End	Late September

freely growing wildflower strips (Figure 4). We have been trying to understand if wildflower strips, which are used to benefit the natural control of insect pests, have any adverse effects on resource acquisition, tree growth, and fruit yield and quality.

The Consortium members are also interested in timing of key pruning work in the orchard. They want to learn if any yield penalty occurs from removing top and side vegetative growth before harvest rather than at the end of the season, when all of the fruit has been picked.

NIAB is working with the new Consortium on the provision of additional research and demonstration projects that are considered to be of highest priority for the industry. NIAB will formulate new research proposal bids to be submitted to the principal research funding organisations to supplement the work already being funded by the plum industry.

Additionally, a major shift has occurred under the new funding arrangement for the Centre. The funders are keen to engage far more with the scientists and farm staff at East Malling to help shape the research and development carried out on their behalf, and it is hoped that this will lead to a more rapid uptake of the research outputs.

Figure 3. The Plum Demonstration Centre Consortium members tour the orchard at East Malling

2022 has not only brought a new approach to the management of the PDC, it has also seen the release and naming of a new early plum variety, launched at the industry's summer trade show Fruit Focus in July (Figure 5). Malling™ Elizabeth was, of course, named for Her Majesty The Queen in her Platinum Jubilee year, a decision that is even more poignant following her death in early September.

The variety, formerly named P7-38, offers growers a high quality Victoria-like plum which produces attractive large, firm red/purple fruits, with excellent flavour and perhaps most importantly, a very early season, cropping before Opal and some 6-7 weeks earlier than Victoria.

www.niab.com/plum-demonstration-centre

Figure 4. The Plum Demonstration Centre Consortium allows research into the exact water needs of commercial plums

Figure 5. The plum variety Malling™ Elizabeth was launched in July

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Responding to emerging challenges in 2021/22

A review of NIAB agronomy membership services

Despite remarkable challenges, the 2021/22 season was agronomically average; whilst variable between locations, disease levels in most crops were average or below and harvest yields, although variable with soil type and crop, were average to good.

Yes, a dry spring turning into a very dry summer with heat from early July had its effect, especially on lighter land but overall crop performance was remarkably good for the rainfall and earliness of harvest. The worst affected combinable crop were beans, particularly spring beans which for some were harvested six to eight weeks early with an associated reduction in yield, albeit with some good crops too. Winter oilseed rape was variable, as usual, but average to better generally. Wheat yields were average or better and some spring barley was exceptional. The effect of the season on later harvested crops such as potatoes, sugar beet and particularly maize may well be more profound.

However, the greatest challenges come from global factors. Energy supply, war and post-covid inflation not only supported crop values but vastly increased the cash requirements to fund fertiliser, fuel, energy and other inputs. Farmers had difficult decisions to make in the spring about nitrogen rates – should they stick to traditionally required rates and maximise yield and returns in 2022 or reduce nitrogen based on economic models and save some cheaper nitrogen for the 2022/23 season. Generally, it appears to be a 50:50 split between the different strategies and, it could be argued, neither strategy was wrong.

The membership team at NIAB reacted quickly to the emerging challenges in 2021/22. Last autumn we were the first in the industry to publish detailed trials, economic data and tools for members, based on over 130 trials over 20 years, around the fast-developing nitrogen cost issue to allow decisions to be made. In addition, the regional agronomy team has also met its promise to provide a hybrid member events system, based on in-person and virtual meetings, and will continue to do so as we move into the on-going challenges of 2022/23.

Andrew Watson is NIAB's regional agronomist in the East of England and Head of Membership Technical Services. His background is in independent agronomy with over 25 years' experience across Norfolk and Suffolk. He served as the chairman of the Association of Independent Crop Consultants (AICC), as well as director for nutritional and legislative affairs.

NIAB's agronomy services provide research and on-farm advice to a large farmer and industry membership base, with a range of packages translating the most recent science and the best practice into on-farm strategies.

Visit www.niab.com to sign up online and try the 90-day free taster.

The NIAB Regional Agronomists at the 2022 Cereals Event (from left to right: Patrick Stephenson, Syed Shah, Will Vaughan-France, Andrew Watson, Poppy de Pass, Steve Cook, Gary Rackham and Keith Truett)

The membership service in 2022

As a response to the challenges within UK agriculture and agronomy, we are constantly evolving NIAB's research alongside results delivery and subsequent advice to members. Here we summarise how NIAB has dealt with the key issues and opportunities seen in the past harvest year and how the membership and wider NIAB team has adapted to provide practical, relevant and topical information to members.

New regional staff

Our team of regional agronomists expanded from six to eight over the past 12 months. Gary Rackham joined the team in the east, providing one-to-one advice to members across Norfolk and Suffolk. Gary also became involved with member events and advice, demonstrating across the busy summer events schedule. Will Vaughan-France works mainly in the south-west, providing one-to-one and regional agronomy services to members. He also has a national role around membership promotion and future services.

Nitrogen

The 2021/22 season saw substantial price rises across nitrogen and other fertilisers, partly due to energy prices but also due to supply shortages of certain products. The regional agronomy team responded quickly to this changing environment to provide detailed guidance of economic fertiliser use, alternative sources of nitrogen and other nutrients such as sulphur, based on the wealth of trial data available within NIAB.

At the point of writing, it is clear there will be significant supply issues going into 22/23 particularly due to large cuts in production of ammonium nitrate in the UK and across Europe. The RA team will continue to respond as this situation develops to provide timely advice to members.

Members' survey

NIAB conducted a detailed survey of members in 2022 to gain an improved understanding of how our membership resources are used in on-farm decision-making and how members rank the importance of different topics, including emerging challenges. The results have already fed into our trial plans for 2022/23. The results demonstrated a high level of satisfaction amongst members, but the survey will also guide us in continuously improving the service we offer members.

Field trials

NIAB funds over 100 field trials each year for our membership. In 2021/22, work was conducted in 11 different crop species, including increased work in spring crops and crop nutrition in response to member requests. With the evolving needs of farming businesses, the range of trials has become more diverse. NIAB added a new centre for farming systems work in Hampshire, at Sutton Scotney, to augment similar work in Norfolk and Suffolk. As ever these trials will be reported to

members between now and the end October as the data is analysed.

Ryegrass survey

In 2021/22, in conjunction with Bayer Crop Science, NIAB commissioned the largest survey of ryegrass resistance ever done in the UK. These results will be reported in detail this autumn but the headlines include around 10% of samples showing flufenacet resistance and just over 25% showing resistance to both ALS and ACCase contact herbicides. This indicates significant challenges in controlling this weed but, as ever, members have been supplied detailed guidance in their publication *Agronomy Strategy 2* which has been extensively rewritten and expanded to account for recent research and new product introductions.

Future member services

In conjunction with the investment in new staff resources, the services on offer to members from the regional agronomy team have been expanded to provide one-to-one strategic advice from regional agronomists in addition to the main membership offer. If current members wish to know more about this additional offer then please speak to your local regional agronomist.

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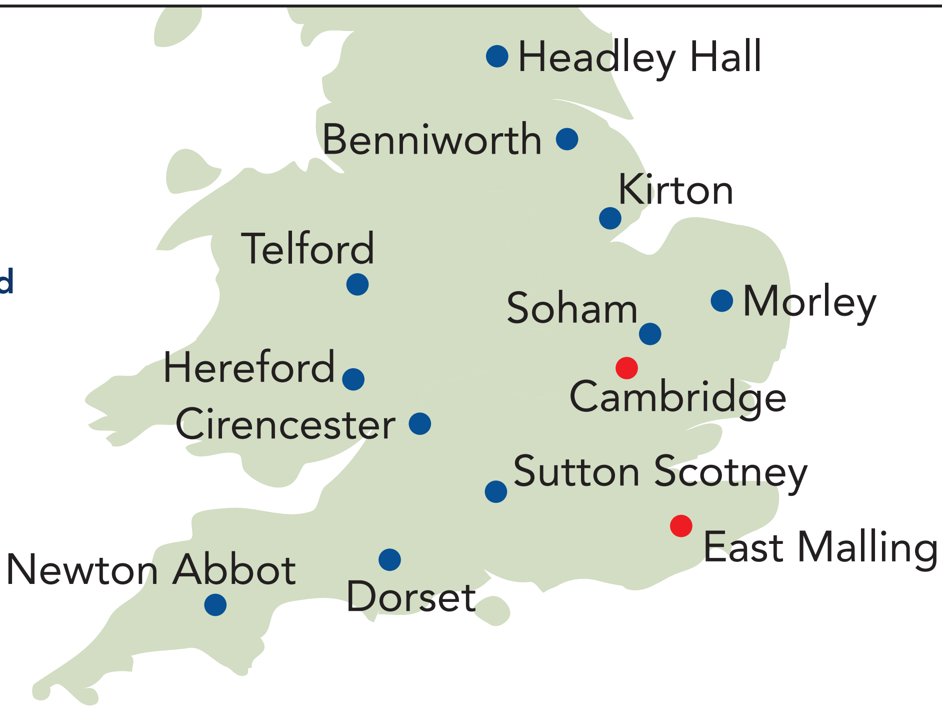

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