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Landmark

Meeting the challenges of lowland peat farming

Sphagnum moss is common on peatland and wetlands

In this Issue

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Regenerative agriculture – hype or hope?

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

Major food and drink producers, retailers, NGOs and even high street banks are moving rapidly and in serious numbers to embrace regenerative agriculture as the solution to a more environmentally responsible approach to farming, with associated benefits for improving soil and water quality, enhancing biodiversity, reducing synthetic input use and conserving precious natural resources.

A year on since our *Landmark* issue (no 50) devoted to the topic of regenerative farming, it is great to see how much the term is in everyone's mouth: it is mainstream. Some of the large food companies are making similar pledges about their commitment to use foodstuffs produced by growers following regenerative farming principles.

There has been much debate of late about what regenerative agriculture really means. The lack of clear definitions has led some to suggest that it is simply greenwash.

Questions also persist over whether the economics of regenerative agriculture stack up at the farm level and, at a time of mounting concern over the impact of climate change and war in Ukraine on global food prices and security of supply, what impact a large-scale switch to regen-ag practices would have on our domestic food production capacity without bringing more land into production.

Examples of bicropping and alternative crops showcased at the 2023 Cereals Event by NIAB

Trials at Rothamsted Research since 2017, for example, involving 24 different cropping systems combining a variety of regen-ag practices have so far shown that, in the short-term, reduced tillage invariably results in lower crop yields, and that sophisticated soil management strategies alone cannot be viewed as the short-term fix for more sustainable food production.

As we mourn the recent passing of Dr MS Swaminathan, one of the fathers of the Green Revolution, it is important we reflect on the successes of agriculture. In the past five decades the global population has doubled to reach the iconic eight billion figure in November last year.

About 10% of the world population will go to bed hungry today: this is unacceptable. But if we go back to the time when Borlaug, Swaminathan and other colleagues set the basis for the great leap in agriculture productivity that resulted in the Green Revolution, that figure would have been 30%. Not only have we managed to keep up with massive population growth, but we also reduced hunger and extended life-expectancy at a remarkable pace.

As we are facing the challenges of climate change and the requirements to grow crops that are healthier, environmentally friendlier and profitable, the question we should ask is: can we sustainably intensify the way we produce food? The technologies and strategies behind soil restoration and regenerative farming stand at the intersection of these challenges.

One of the strengths of regenerative farming is its lack of prescription, and flexibility, provided its guiding principles are observed. These guiding principles are founded on well-established farming practices, many of which have been studied by NIAB as part of our applied agronomy research programmes for many years, for example in terms of longer, more diverse rotations, use of cover crops, minimum and no till cultivation systems, and improvement of soil health.

Many progressive NIAB members I have spoken to about their experiences with introducing regenerative farming practices on a commercial basis are adamant that they need that flexibility, and all the tools in the toolbox such as glyphosate to control weeds, or novel genetics to increase productivity while reducing dependence on chemical pesticides and fertilisers.

But while the success of regenerative farming may lie in its flexibility, and the diverse range of ways in which its guiding principles can be delivered, there remains a lack of commercial-scale data to inform best practice – in other words a lack of independent science which will incentivise farmers to adopt soil restoration production practices, allow the industry to demonstrate its sustainability credentials to value chain partners, and to communicate with consumers the benefits that come from a more science-based approach to agricultural production.

As former Teagasc director Professor Gerry Boyle observed recently: "..*fluffy claims are not enough, and robust scientific data is needed to assess the power of regenerative agriculture*."

In short, there is a need to provide the science which can scale-up and underpin the credibility of regenerative farming systems, based on a recognition that practices focused on increasing soil organic matter, avoiding erosion, and reducing disturbance to the soil are entirely compatible with sustainable intensification and precision agriculture.

NIAB's vision of regenerative farming is that it shares with sustainable intensification and precision agriculture the aim of optimising productivity – producing more from less – while at the same time protecting and improving the condition of the land and surrounding environment. This is also reflected in the focus on lowland peat farming in this issue of Landmark and the work NIAB and other organisations are doing in the restoration and future management of these landscapes that contribute so much to UK food production, while enhancing biodiversity and reducing carbon emissions.

NIAB's Head of Farming Systems Dr Elizabeth Stockdale features in a short film from McCain UK on the positive role of regenerative agriculture in food production (https://www.youtube.com/watch?v=MEo1t-_mMT4)

In that sense regenerative agriculture is neither hype or hope, but just a sensible way of farming that should be supported by solid evidence-based science.

That's why NIAB is preparing the ground for a major research effort focused on delivering the science behind regenerative agriculture, building on our independence and research leadership in soil science, variety testing, rotational agronomy, precision agronomy, cover cropping, data science and water use efficiency.

NIAB's objective for this ambitious programme is not only to be the go-to place for independent advice on issues such as variety selection, cover crops, rotations and agronomy, but also to develop the metrics by which the sustainability of regenerative agriculture practices – in terms of resource use and environmental impact – can be benchmarked and monitored over time.

This outcomes-focused approach to data collection and assimilation will be essential not only to understand and drive best practice at farm level, but also to provide information to customers and ultimately consumers about the comparative sustainability impact of each unit of food produced, whether that is a loaf of bread, a punnet of strawberries, or a bag of potatoes.

We also plan to integrate regen-ag objectives into our genetics and pre-breeding activities, for example by improving the performance and viability of N-fixing pulse cropping options, investigating novel crop opportunities, and even exploring the potential for cover crops to become an additional source of revenue within the rotation, as is already happening in the United States with the development of gene edited Covercress™ as a source of high value oil and animal feed.

We are confident that a progressive, science-based approach to regen-ag, embracing innovation and harnessing the power of large-scale data, offers the potential for high-yielding, profitable crop production to go hand in hand with reducing agriculture's environmental and climate impacts.

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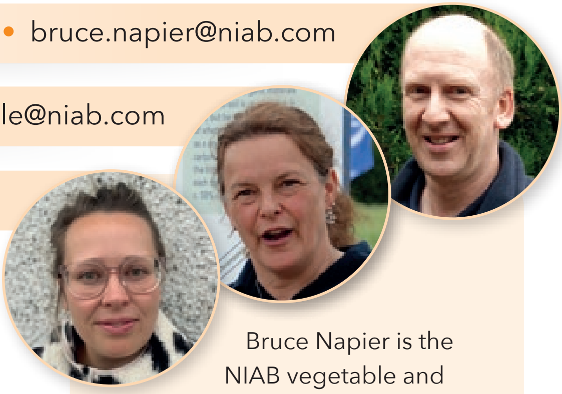
Jenny Rhymes, UKCEH



It's a triple challenge for lowland peat

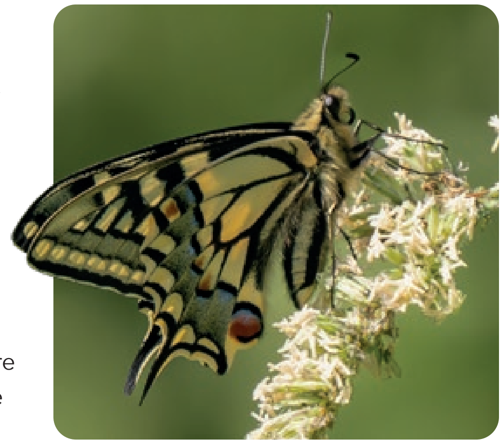
Globally humanity is facing a triple challenge, to deliver food security, maintain/restore biodiversity and mitigate climate change. In this context, drained lowland peat landscapes have come under particular focus.

Lowland peatlands have formed under a wide range of wet conditions across the UK ranging from low-nutrient, acidic and bog-like through to high nutrient and base-rich. In the north and west, lowland peatlands often support rain-fed raised bogs, whereas in large estuarine lowlands, such as the East Anglian Fens, Humberhead Levels and Somerset Levels, peats often formed in river and groundwater-fed reed/sedge swamps. These landscapes formed over thousands of years as marine and estuarine clays and silts were deposited as a result of the advance and retreat of the sea, whilst rivers slowed down as they reach the lowlands, deposited their sediments and created intermingled peaty wetlands and wet woodlands. Small peatlands also occur throughout England along many river valleys and in wet depressions. A large number of insect, bird and animal species were associated with these diverse intact lowland peatland and wetland habitats. Large areas of lowland fen now provide the only habitat for many threatened bird species including common crane and the rare spotted crake. As a result of habitat loss, some species are now rare, for example the swallowtail butterfly which feeds on milk parsley and is restricted to the Norfolk Broads (Figure 1).

Management of water within England's lowland peat landscapes happened from their formation thousands of years ago, but extensive drainage schemes largely took place from the 17th century onwards as venture capital was invested in advance, with the 'Adventurers' receiving reclaimed land in repayment. The drainage effort was immense with the construction and maintenance of many large drains to move river water quickly away to sea coupled with windmills to drive pumping stations that moved water from the intervening lowlands up to the drains.

Successful drainage of peat leads to a fall in the land surface as a result of collapse and shrinkage of the peat soil directly as a result of the removal of the water (which occupies over 50% of the peat volume) and then as a result of the compression of lower peat layers because the drier peat layers no longer 'float'. As the organic materials within the peat are exposed to air, oxygen-fuelled decomposition processes begin. Loss of peat soil is well documented with the land surface of The Fens, where it is now considered to be ca. 10 m below where it was before drainage began; in many lowland peat landscapes, estimates of peat loss in lowland peatland used for agriculture are commonly 0.5 to 2 cm per year. In addition to decomposition, wind

Figure 1. Swallowtail butterfly on milk parsley



Bruce Napier is the NIAB vegetable and salads crop specialist with 18 years of experience in this role after 15 years as a plant pathologist. He manages and delivers research and contract trials for vegetable and salads crops and his knowledge of these cropping systems made him the ideal candidate to join the project looking at paludiculture and the "triple challenge". Bruce contributed to the Defra report on underutilised crops – a study which will inform development of future cropping systems in the UK.

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. She currently leads the Paludiculture Engagement project.

Dr Jenny Rhymes is a greenhouse gas flux scientist at UKCEH, based in Bangor. Her research career to date has focused on understanding the implications of agricultural land uses and management on key ecosystem processes in the face of climate change, whilst also developing practical solutions that can support the transition towards more sustainable land management across a variety of ecosystems including wetlands, grasslands, and cropland. Her current work addresses the challenges in lowland peat landscapes and seeks to develop practical and economically viable opportunities to reduce emissions from these deeply unsustainable yet highly productive agricultural systems.

Figure 2. Peat soils are used intensively to grow vegetables to meet UK market demand

erosion is also responsible for losses, up to 0.25 cm peat per year, particularly during wind blow events where dry surface peat is blown off the fields. Falling land surfaces mean that over the centuries, the pumps have needed to get bigger and consequently the main drains stand further and further above the surrounding land.

Lowland peat soils were drained to provide increased opportunity for farming. Today, grasslands are common in the Somerset Levels supporting dairy production, whilst in the Lancashire Mosses, Humberhead Levels and Fens, arable and horticultural systems dominate. These systems are often locally adapted to the black soils and are highly productive, for example The Fens account for around half of the most productive (termed Grade 1) agricultural land in England. Hence, although it covers less than 4% of England's farmed area, The Fens produces more than 7% of England's total agricultural production with a significant concentration of vegetable and salad production; overall more than 40% of England's fresh vegetables are grown on lowland peat soils. The main vegetable crops associated with lowland peat soils are celery, lettuce, brassicas, leeks and potatoes.

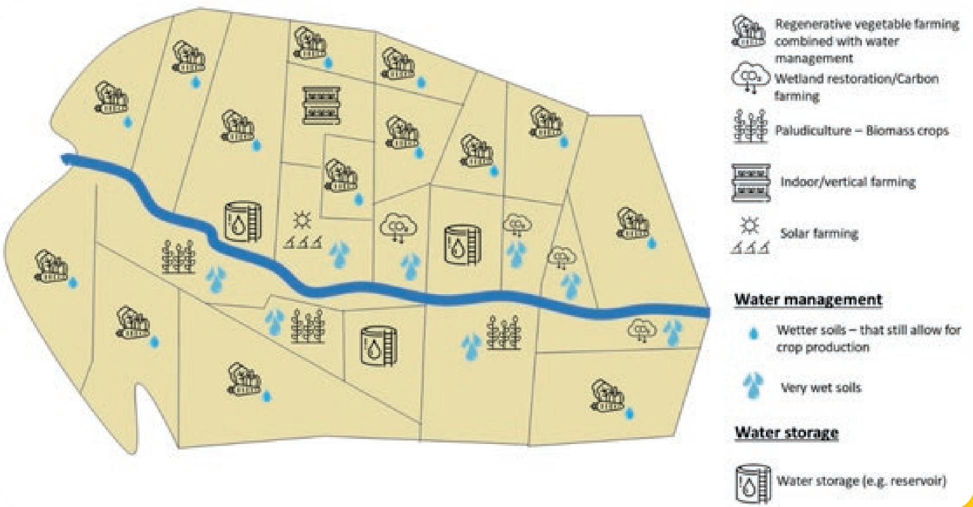
Greenhouse gas (GHG) emissions associated with drained peatlands are high and have a high intensity (Figure 2). These emissions largely result from the decomposition of the organic soils releasing the stored carbon as carbon dioxide (CO_2) to the atmosphere. About 3% of the total GHG emissions from all sources in England are from lowland peatlands drained for agriculture. There are also significant methane losses from ditches and drains in these landscapes, but they are not yet well quantified. Detailed research work led by Professor Chris Evans, at the UK Centre for Ecology and Hydrology (UKCEH), has confirmed that it is the depth of aerated peat that is the dominant control on GHG emissions from managed peatlands. This work has shown that manipulating water table depths to near surface levels (0 to 20 cm below the surface) offers the optimal carbon derived GHG mitigation in lowland peat. Within this range it is likely that CO_2 emissions will be reduced to zero and, if peat-forming vegetation is present, the system will become a carbon sink. Other GHG emissions are also likely to be close to zero provided the field does not become continuously flooded. There is a common perception that re-wetted lowland peatlands can only be managed for conservation, however there are a growing number of options to manage re-wetted land commercially, e.g. paludiculture and carbon farming.

Significant reductions in GHG emissions reductions can therefore be achieved if the water table can be maintained through changes in agricultural water management and crops grown, even if land remains in crop production. Opportunities for wetter cropping could include plants used for bioenergy and/or construction material. Recent research is also including food crops such as celery and watercress. To tackle these issues it requires a combined, landscape-scale approach that is likely to have a mosaic of continued high

Figure 3. Relative impacts of different cropping landscapes on greenhouse gas (GHG) emissions intensity (i.e. carbon dioxide equivalents (CO_2e) expressed per calorie produced) reveal the very high relative impact of cropping systems on drained peatlands largely in boreo-temperate regions (with hotspots in northern Europe) and in tropical areas (with hotspots in Indonesia). *Data from Carlson et al. (2016) Nature Climate Change. DOI: 10.1038/NCLIMATE3158*

	% of global calories	% of global GHG	Emissions intensity (tonnes CO_2e per M kCal)
Overall for crop production			0.16
Dryland cropping systems	84	20	0.03
Paddy rice	15	48	0.58
Cropping systems on drained peatland	1.1	32	3.70

Figure 4. An example of a new landscape mosaic in a rewetted lowland peat landscape; there is increased water storage (e.g. farm reservoirs) and a wider range of land-uses and habitats *(Source: WWF)*



value cropping systems under wetter conditions (arable and vegetable crops) integrated with alternative wetter land use opportunities, e.g. carbon farming, together with an integrated system of water management (Figure 4).

These landscape-scale changes may help to deliver national net-zero carbon emission targets and enhance biodiversity within the lowland peat landscape; however, they are very unlikely to maintain the current level of crop production. Therefore there will be a need to increase crop production elsewhere to maintain current levels of food security. In particular delivering the triple challenge would require some expansion of vegetable production elsewhere, on mineral soils or in glasshouse/vertical farming systems. Moving cereals currently grown on organic soils to mineral soils could also free up land for re-wetting, helping to offset continued emissions from vegetable production on organic soils. It could also permit movement of vegetable production from high-emitting deep peats to lower-emitting wasted peats, or permit vegetable production to occur over larger areas but at a lower intensity, e.g. with dynamic water level management or with vegetables being grown in rotation with crops that require less drainage. It is also important to note that for retailers and processors maintaining sufficient crop production of the right quality (with the specification varying by market) is often more important than maintaining overall productivity.

Land suitability, availability and cost, will be major factors determining the potential to relocate vegetable production systems. Relocation of vegetable crops from lowland peat soils to new locations on mineral soils is most likely to be met by expansion of the rented land base used by specialist growers (with the specialist machinery and expertise needed) who would then drop into arable rotations managed by others. Whilst it is accepted that there is a finite availability of quality land with the infrastructure required for growing vegetables, this land base cannot be identified and quantified easily. Though horticultural crops are grown throughout the UK, commercial production for major supply chains of each vegetable crop type is often heavily concentrated in regional pockets. This has allowed efficient and centralised marketing, together with optimisation of logistics to reduce losses during transport and processing. Increased production costs and logistics challenges are the major barriers to the relocation of some vegetable crops away from lowland peat soils.

The Climate Change Committee's Land Use Policies for a Net Zero UK report developed a scenario involving full restoration of at least 50% of upland and 25% of lowland peat by 2050, as part of an overall land-use strategy to achieve net zero. Similarly, the CCC's 'Balanced Net Zero' scenario for agriculture and land use in the UK's Sixth Carbon Budget went further, suggesting rewetting or implementing sustainable management on 75% of lowland peat cropland and rewetting 50% of lowland peat grassland by 2050. Despite the high level of ambition set out in the Sixth Carbon Budget, restoring 50% of cultivated lowland peatland could have major implications for rural economies and the UK's food supply, with a risk that the environmental costs of food production, including greenhouse gas emissions, are simply transferred overseas. On the other hand, a strategic combination of restoration, technological innovation and the reconfiguring of production systems in locally-adapted land use mosaics could achieve a combination of food security, biodiversity and climate change mitigation benefits.

Drained lowland agricultural peat landscape near Ely

WWF's ambition is to halve the environmental impact of UK food baskets by 2030; the underlying driver for this focus is the fact that 60% of global diversity loss is caused by the food system. WWF has built ambitious partnerships to identify and address key issues and support change. This is described in the WWF Basket Blueprint for Action. In 2021 this set out an ambition to restore and sustainably manage 70% of the UK's two million hectares of peatlands and tasked food retailers with mapping out and reducing product sourcing from lowland peat. WWF-UK commissioned a project to help understand the context behind objectives and provide resources to encourage action. UKCEH and NIAB worked in partnership to deliver this work for WWF; the full technical report is now available.

The Future of UK Vegetable Production: Technical Report (WWF)

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Robert Caudwell, LAPTF Chair

The Lowland Agricultural Peat Task Force

Water management specialist, Chair of the Association of Drainage Authorities and former Chair of the Regional Flood and Coastal Committee, Robert Caudwell summarises the recommendations of the Lowland Agricultural Peat Task Force in combating climate change through the sustainable management of UK lowland peat soils.

We have all watched the news this summer of catastrophic wildfires in Europe and North America, way beyond the normal pattern of events. Although the UK has not suffered the extreme high temperatures we saw last summer, the threat of drought after a very dry June receded with a dripping July and August which has made harvest for the farming community more difficult than recent years.

The evidence for dramatic climatic change happening now is indisputable; predictions of change being maybe 20 years away are being adjusted down by the circumstances of the past two years. The need to act on reducing carbon emissions is urgent; we cannot be complacent and think this is just planning.

The necessity in reducing emissions from lowland peat soils that are used for agriculture should be clear to us all. However, they are also our most productive soils and produce the majority of our home-grown vegetable crops that the UK should be producing, and consuming more of, to reduce food miles and have a healthy diet that includes fruit and vegetables. With this consideration Defra set up the Lowland Agricultural Peat Task Force in January 2021 to find a more sustainable way of farming lowland peat soils, through significant reductions in emissions whilst maintaining the ability to grow agricultural crops, present and future. Members of the national Task Force were drawn from a wide range of stakeholders and interests; the full list of members is available on the Chair's Report published on www.gov.uk.

The challenge was to find an agreed way forward, but the members of the Task Force were determined that the issue is so important that failure was not an option. The Task Force was supported by four regional groups to ensure local knowledge and experience would be reflected in the Report, alongside local peat 'farming champions' who were the regional leaders and innovators in the four regions of the Northwest, Southwest, Eastern (Fenland and the Norfolk Broads) and the Northeast. Eastern had two local champions as the issues and solutions for The Fens and The Broads could be significantly different.

The Report was published by Defra on 29th June 2023, with 14 recommendations to Ministers to consider. They accepted all the recommendations and are making good progress on implementing them within their remit.

Grants are available under the £2.2 million Lowland Agriculture Peat Water Discovery Pilot fund, with a 27th October 2023 closing date, and expressions of interest are asked for the £5.45 million Lowland Agricultural Peat Small Infrastructure Pilot (LAPSIP) grant aid scheme. There is also grants for the £5 million Paludiculture Exploration Fund and support for a research and development programme.

Lowland Agricultural Peat Task Force Chair's Report (June 2023)

Available on www.gov.uk

This independent report makes recommendations for a more sustainable future for agriculture on lowland peatlands in England

Phil Brewin

The Tealham Moor tilting weir in Somerset

Ian Moodie

Maintenance work by Welland and Deepings Internal Drainage Board

The Report's recommendations included:

New water for peat and more water level management control

Recommendation 1 – a place for peat in planning more strategically about water. Water resource management plans are being drawn up across the country and there was a strong feeling that peatland management needed to be included in the list of water resource requirements going forward. During the task force discussions, all the water resource group chairs were contacted to highlight the need to take peat soils into account.

Recommendation 2 – new investment in water storage, management and control. It is clear that if watertables are to be raised and kept at a higher level, more infrastructure will be needed as in LASIP pilots, but also, water needs to be stored when there is too much to top up systems in times of drought.

Recommendation 3 – legal protection and powers for managing water in the interests of carbon. At present water can be managed to reduce flooding and for the benefit of wildlife habitats, but carbon reduction cannot be taken into account as a benefit when applying for grant aid.

Enabling more sustainable ways of farming on peat soils

Recommendation 4 – public money for wetter modes of farming on peat soils. The available grants are set out in this article, but ELMS is critical for farmers to feel support for new ways of managing peat soils.

Recommendation 5 – viable opportunities in private finance. Version 2 of the carbon code includes the opportunity for carbon credits, but they must work with and complement ELMS.

Recommendation 6 – technical advice on keeping soils wetter, building on the catchment advisor role of helping farmers understand the new ways of managing soils and the support available.

Supporting people , partnerships and economies

Recommendation 7 – building on bonds already formed; in all the regions great partnerships are starting to form that need to be built on. I am a strong believer in partnership as the only way to deliver sustainable change

Recommendation 8 – ensuring policy and legislation support regulators, as too often policy, legislation and regulation seem to work against each other rather than in support.

Recommendation 9 – raising the public profile of lowland agricultural peat soils. The majority of people, outside the stakeholders already engaged, just think of peat soils being about uplands and moors. Lowland agricultural peat needs a higher profile as the opportunity to make significantly reduce emissions are in the lowland.

Recommendation 10 – undertaking a socio-economic assessment of new measures, with an impact assessment of any changes to policy and support regimes.

Driving forward science and innovation

Recommendation 11 – understanding the depth and condition of lowland peat. The evidence base of lowland peat depth and condition is not detailed enough to make local decisions on where the most important peat soils were. The work that Fenland Soil has been undertaking is vital to enable better understanding of peat soils.

Recommendation 12 – more large-scale field trials and modelling to demonstrate to growers and farmers that this can work at field scale. It needs to be replicated in all regions to create regional recommendations; what may work in the Northwest cannot be assumed to work in The Fens.

Recommendation 13 – advancing new technologies, for example automation may help where wetter soils need lighter machinery. Vertical farming can help to maintain/increase production whilst making way for paludiculture.

Recommendation 14 – adopting the roadmap to commercially viable paludiculture, which has the potential to significantly reduce emissions but has to be commercially viable before farmers are willing to take it up on a large scale.

Megan Hudson, Fenland SOIL

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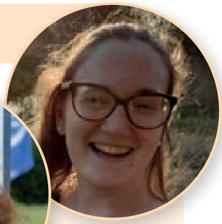

Redesigning lowland peat landscapes with farmers

The farming community is a vast repository of practical, in-depth knowledge of soils and land-management and these data are at a far higher resolution than most national datasets on which research and policy are based.

In the UK, local knowledge of landscape and soils (LSK) has rarely been a core component of soil assessment or land management policy. LSK is defined as "*the knowledge of soil properties and management possessed by people living in a particular environment for some period of time*". However, mounting evidence shows: i) the value of LSK integration into participatory soil surveys; and ii) exclusion of LSK often results in the failure of scientific interventions to improve land use, especially where scientific data are lacking.

The failure to exploit local knowledge has been recognised as a barrier to the achievement of the England Peat Strategy. In early 2022, NIAB and Fenland SOIL were awarded a £96,000 Natural England Peatland Restoration Discovery Grant to assess the feasibility of bring together the informal, fragmentary, and descriptive knowledge of land managers to show how this information can be brought together with that of other experts to help to address the challenge of unsustainable management and carbon loss in the Fens. The aim of the work was to unlock barriers to re-wetting and restoration by co-creating an integrated evidence base and developing Opportunities Maps at the local scale with the stakeholders, who will manage the resulting land-use or land-management change in practice (mainly farmers and Internal Drainage Boards (IDBs).

Lowland peat systems are commonly a mix of peat soils of various depths with associated organo-mineral soils and hence a mosaic of management options is very likely to be needed to achieve effective long-term rewetting at catchment-scale. Any peatland restoration, with full and maintained rewetting, will need to be integrated effectively into catchments with other changes in land management practices. These actions require close co-operation between water and land managers at local scales; in addition, much can be learned across farms and IDBs and hence a common methodology is needed to allow peer-peer and peer-expert reflection and learning between IDBs.

Hydrology is key to changing the land management practices of lowland drained peats to reduce emissions. Therefore, this methodology is designed to be deployed over whole hydrological units and therefore should be done across either an internal drainage board or a river catchment area. We identified three IDBs, covering just over 11,000 ha, within Cambridgeshire as pilot areas to develop and test the approach. The Project took a mapping-led approach as a mechanism, initially for showing and sharing different views and then as a way of assembling, relating, revealing, sifting and speculating about land-water relationships, their interactions with biodiversity and the historic environment and the functions of restored peatland within these specific Fenland catchments.

The project worked closely with farmers and land managers in the three drainage boards in the pilot area and, in addition to carrying out the mapping process, also delivered training on soil identification, biodiversity and use of survey kit such as soil augers and pH

Figure 1. Discovery Group farmers exploring the watery ecosystem of Fens ditches

Megan Hudson studied BSc Geography at the University of Leicester where she developed an interest in peat soils and the environmental issues linked to agriculture. She leads and co-ordinates the work of Fenland SOIL, a not-for-profit members organisation that aims to inform and develop 'whole farm' land use policies, aimed at achieving climate change mitigation and biodiversity enhancement in the Fens.

Elizabeth Stockdale – see page 4.

Figure 2. Discovery Group farmers exploring Wicken Fen

meters (Figure 1 and 2). This local information was brought together with expertise on mapping peat soils, water management, agriculture, local heritage and biodiversity-led peatland management.

Farmer-led mapping approaches were used to provide field-scale maps of the existing extent of peat soils, together with ground-truthing for condition and depth. A group of pilot farmers had worked together to develop a common lexicon to describe the range of soils across their farms (see box for examples). This was used as the basis for farmer maps (often using felt-tip pens on existing farm maps; e.g. Figure 3); these were transferred to provide an underlying GIS soils layer.

By working with a local group of farming experts, but from outside the specific IDBs to ensure independence, it was possible to agree metrics that could be rapidly collated to give productivity indicators relevant to the cropping systems in the area of study. This approach was applied at field/field zone scale to link farmers' knowledge of constraints to production and productivity, and then used spatial integration approaches to provide integrated field-scale maps of land-use productivity. Farmers used simple keys to score fields or field zones in terms of several productivity factors including: yield potential for a reference crop (here winter wheat); flexibility (range of crops that can be grown); resilience; and soil variability. These data were combined to give a qualitative productivity index and no individual data were shared. In IDB workshops farmers discussed and peer-reviewed their inputs.

Many agronomists, other farm advisors and some policymakers, began engagement with the project team with a very poor understanding of the landscape history, current approaches to land and water management and the scale and scope of the changes needed within the Fens landscape to deliver GHG mitigation. Much of the discourse began with an assumption that approaches taken in the uplands (for peat restoration) and/or on mineral soils (e.g. land use change from cropping to grassland/woodland; regenerative practice in cropping systems) could be transferred simply and deliver GHG mitigation in these lowland peat systems. The project focused on creating and building understanding at the local scale within IDB working groups.

Farmers were actively engaged with the processes. Partner farmers encouraged others within the IDB to attend meetings and engage with the project (Figure 4) with a high success rate finally achieved (around 80% of all the land in the districts, with the majority of land not engaged in the project being mineral soils on the edge of The Fens area adjoining the Brecklands). All farmers proved to be excellent informants. For soil/peat mapping there had been some concern raised in advance by the specialists that these data would be weak and not well aligned with the specialist description, classification and mapping approaches deployed in formal surveys. However, on review of the outputs, the experts concurred that the spatial detail of farmer mapping was excellent and well-aligned with existing mapping (where available) at 1:63,360 or 1:50,000 scale. Overall, it was agreed that the farmer-collated soil information gave useful scoping data that could be used to guide targeted ground-truthing (with expert soil description as appropriate) to support mapping verification or land-use planning.

We had expected to be able to draw on IDB waterway maps and modelling of water-levels, to provide a baseline hydrology layer. We had also planned to use the IDB Biodiversity Action Plans developed by the IDBs with on-farm management options for biodiversity to create catchment habitat and habitat potential maps. However, the information held for hydrology and biodiversity at field or smaller-scale within IDBs was more sparse and less spatially explicit than had been anticipated. A hydrology map was created by bringing together farmer knowledge of water levels and opportunities for water management at field scale with qualitative data drawn from local IDB expertise.

In all IDBs, discussion workshops to review the integrated opportunity maps identified how changes to IDB- and more local-scale water management could be made to allow landscape regeneration and rewetting. Within these drained catchments in the lowland peat landscape of the Fens, it rapidly became clear that the main limiting factor to any peatland restoration or rewetting is local-scale water management (together with associated costs of capital works and on-going running cost). The requirement for co-operative working to make changes to water levels is built into IDBs. Within the IDBs a general principle is that water levels cannot be changed to benefit a particular landowner, if that change will disadvantage other landowners. This means that to make changes to water levels, landowners be able to isolate their land effectively from other land within the drainage district (this is relatively rare with <5% of the land area in the project IDBs falling into this category) or landowners need to work co-operatively with one another and the IDB engineers.

As rewetting has the potential to impact proximate infrastructure (roads, rail, power etc), especially if taking place at large (>100 ha) scale, it is important to identify and then engage with the relevant providers at an early stage of the conversation. There is currently no simple mechanism in place to identify or facilitate the key routes for engagement with such infrastructure providers.

This process was deliberately roots upwards, other approaches we are aware of are much more technical, desk-top and theory-based. We recognise that both approaches will often be needed as part of a collaborative process but this project has shown that where the specialist input supports a locally-led process, engagement is very effective and that this is more likely to support development of the long-term relationships needed to underpin practical change. This approach is already being adopted with other lowland peat stakeholders in the UK and in peatland landscapes in Europe to adopt and locally adapt the opportunity mapping approach for farmer engagement as part of rewetting and restoration projects. In other landscapes we believe that similar approaches could help support land use and land management change.

The next steps

During the delivery of this project, Defra reviewed and changed the structure of ELMS, re-invigorating Countryside Stewardship to replace the planned Local Nature Recovery scheme. Countryside Stewardship now includes new rewetting options for lowland peat. Farmer feedback indicated this local scale action is favoured by the farmers in comparison with a full ecological restoration. Farmer feedback indicated that local scale action for small areas within the IDBs where water tables are already high or the fields are easily hydrologically isolated will be considered for rewetting by integration into farm led Countryside Stewardship schemes.

Farmers also recognise the potential value of the large-scale Landscape Recovery scheme for land use changes of the scale that is envisaged in the Fens; however, they do not have the capacity working alone to catalyse such proposals. Success in obtaining funding for this project was one of the factors which has led to the creation of the Fenland SOIL farmer-led organisation (from its origin within the CPICC Fenland Peat Committee) to proactively tackle climate issues relating to agriculture and peat in the Fens.

During the project, in October 2022, Anglian Water and Cambridge Water launched the first formal consultation associated with the proposed development of a new Fens Reservoir. This lies just outside the boundary of one IDB within the project but may provide some contemporaneous development in water management infrastructure to facilitate landscape regeneration in the IDB. Farmers within the IDB will work together with Fenland SOIL to explore opportunities for ELMS Landscape Recovery or similar approaches to be used to leverage investment in water management structures for the reservoir to support wider rewetting and landscape regeneration approaches.

Figure 3. A working farm map with soils knowledge added by the farmer

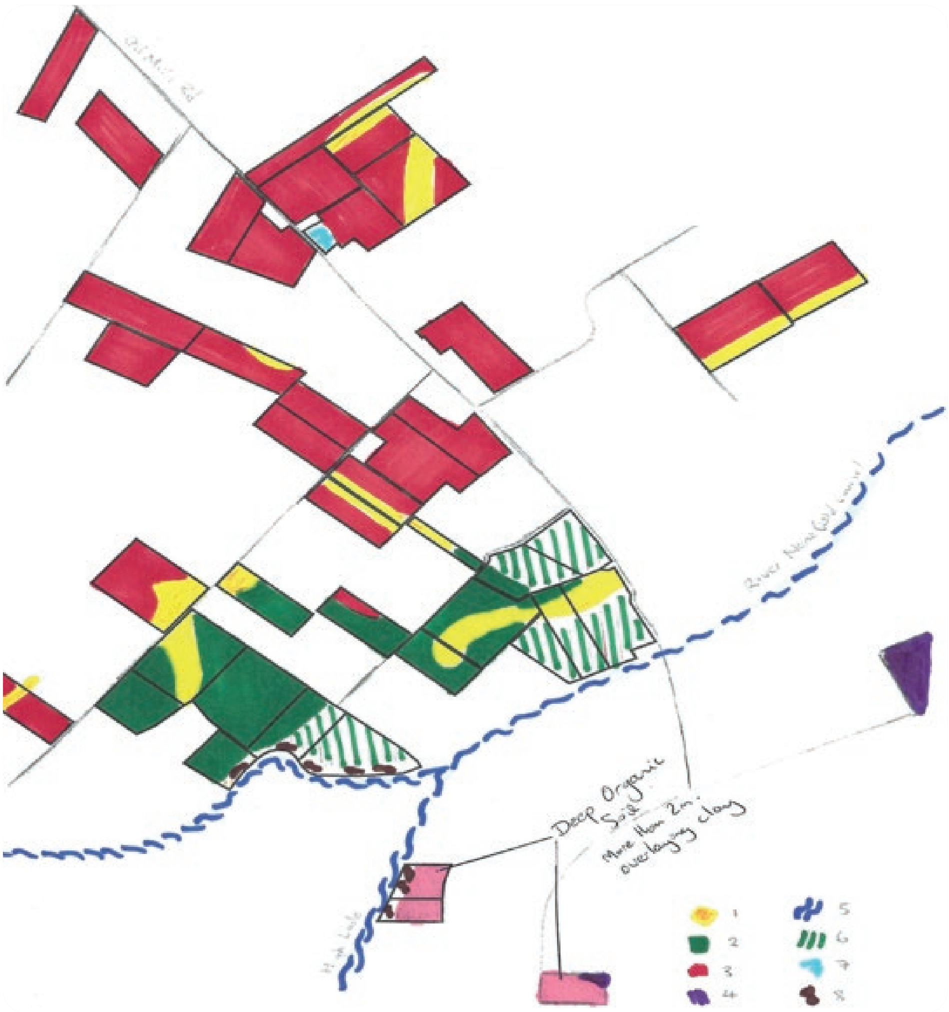

Figure 4. Farmers and experts discuss and annotate the Opportunity Maps

Megan Hudson, Fenland SOIL

Megan Hudson – see page 10.

How farmers are being proactive about lowland agricultural peat

FENLAND SOIL
SUSTAINABILITY | OPPORTUNITY | INNOVATION | LEARNING

Fenland SOIL is an organisation set up by farmers, for farmers, to tackle issues relating to climate change and lowland agricultural peat in The Fens. We are made up of a range of different stakeholders including local farmers, research organisations NIAB and the UK Centre for Ecology and Hydrology, and academic institutions including Cranfield University, University of Leicester and University of Cambridge, alongside environmental NGOs and policymakers.

The aim of Fenland SOIL is to address our lowland peat issue holistically, and from the bottom up, to ensure that best practice is both reasonable and achievable for the land managers that will be responsible for carrying it out. In addition to achieving climate change mitigation through reducing our emissions we also aim to enhance biodiversity, improve best practise with regards to agriculture, support changes to water management, and help develop advances in agritech and regenerative systems on high organic matter soils.

Primarily, Fenland SOIL was set up to address the emissions issues associated with the degradation of peat soils in East Anglia. The Fens landscape has evolved significantly over time and with a great deal of intervention by people, particularly over the past 300 years when drainage efforts have been made in earnest. Factors such as physical shrinkage of our peat soils from water loss, wind and water erosion, and the oxidation of these soils, have led to several metres of soil loss in places across the Fens. This soil loss is important because not only does it mean the loss of a valuable growing medium but also significant carbon emissions that could be a potential barrier to Fenland farming reaching Net Zero in line with both government and industry targets. Estimates suggest that agricultural use of peat on the Cambridgeshire Fens is currently producing around 2.6 million tonnes of carbon dioxide equivalent per year. This equates to around 40% of Cambridgeshire's total emissions.

Fenland SOIL's activity is split into five working groups, each with an industry leader at their head: Farmers Dialogue; Nature-based Systems; Landscape Mapping; Greenhouse Gas Emissions; and Economic and Social Impacts.

Farmers Dialogue works directly with farmers across The Fens and beyond, with 35 members engaging with our work, as well as two major landowners. This group hosts regular events to keep members informed and upskill farmers on things such as improving biodiversity and recognising soils, with farm walks, talks and workshops. Our inaugural event at FC Palmer and Sons, near Stretham, attracted 65 attendees across the industry as part of our Farmers Dialogue group. We also hosted our first biennial *Exploring the future of lowland peat* conference at The Maltings, in Ely, in April 2023 (Figure 1). The conference attracted more than 220 delegates from across the industry, with farmers, machinery dealers, input providers, academics, nature conservation groups

Figure 1. Speaker panel at Fenland SOIL's *Exploring the future of lowland peat* conference in April 2023

Figure 2. Workshop delegates at Fenland SOIL's *Exploring the future of lowland peat* conference in April 2023

Figure 3. Flux tower in The Fens

and many more all in attendance. Speakers joined from Sweden, The Netherlands, Germany and Canada and leading organisations and institutions in the UK such as UKCEH, Cranfield University and the University of Cambridge's Centre for Landscape Regeneration. Delegates also took part in a series of workshops across the two days with Defra designed workshops focusing on the Environmental Improvement Plan and a Fenland SOIL workshop on mosaic landscape management (Figure 2).

The Nature Based Systems workstream is critical to understanding how nature and conservation can be integrated within the farmed landscape across the Fens. It aims to work with farmers, academics and conservation specialists to identify farm system interventions or changes to farm management that can enhance biodiversity in the farmed landscape at the same time as delivering on objectives to mitigate climate change and improve access to water resources.

The Landscape Mapping workstream is key to understanding our soils. Each soil type offers different current and future opportunities for its use, depending on soil properties, peat depth and drainage status. However, most soil maps covering The Fens date back to the 1980s and it is likely that, due to peat wastage, the area and thickness of peat soils has declined. This workstream aims to improve our understanding of the current conditions of Fenland SOIL and the future of land management opportunities. We are doing this through a farmer-led approach using local knowledge to create 'opportunity maps' to then identify the best areas for crop production, less intensive or alternative farming and conservation. The aim is to help agriculture build towards net zero while maintaining the production of food and the livelihoods of farmers.

The Greenhouse Gas Emissions workstream is providing up-to-date figures for emissions in The Fens. Fenland SOIL has five flux towers in operation across the Fens in collaboration with UKCEH and Quanterra (Figure 3). These towers provide a detailed overview of the movement of carbon between the soil and the atmosphere as well as the hydrological and meteorological factors to give a whole view to the state of the soils. This data is then applied to the landscape mapping workstream to ensure that the emission factors are scaled up to the correct soil types. The end product is a detailed understanding of what the soil is emitting and what crops can help reduce carbon and build towards a Net Zero agricultural community.

The Economic and Social Impacts workstream examines impacts of the Net Zero target on business and the Fenland economy. Fenland SOIL is also evaluating how the Environmental Land Management (ELM) Schemes may be able to provide support to businesses to establish regenerative practices without damaging profitability. By working with Defra, we can help shape policy at the highest level. Our aim always being that the government does not leave farmers behind and provides the clarity they require to keep their businesses prospering. The NFU are supporting this workstream allowing us to raise awareness across the farming community, so we have the greatest impact possible.

CASE STUDY

FC Palmer and Sons, Stretham

Luke Palmer, vice-chair of Fenland SOIL, is all too aware of the challenges Fenland growers are facing. Farming nearly 1,700 ha near Ely, Luke has had to adapt to the policy changes brought forward by the local authorities' 'Independent Commission on Climate' report. "We were intent on preventing erosion and degradation – now the situation has been given a different focus," he says, referring to the emphasis on carbon and net zero. Luke's business is diverse including 98 ha of solar panels and an aqua park on one of two reservoirs, as he has "deliberately maintained as much diversity as possible." Luke accepts that some of The Fens could be taken out of production but is concerned about the future if funding is not sufficient, "everyone tells us that diversity is the way forward…but intensifying production is often the most viable option." Water is an essential part of farming in The Fens and Luke hopes that Internal Drainage Boards will play a greater role in order to open opportunities such as localised flooding. The crops that are grown in The Fens feed the nation and Luke maintains that food cropping delivering to traditional markets will always be a key part in the mosaic of agricultural land use in The Fens, but that farmers will be willing to follow the market and explore alternative cropping methods as long as they are viable in a commercial system.

Luke Palmer, vice-chair of Fenland SOIL on his farm near Stretham

CASE STUDY

Oxwillow Biodiversity Recovery

At the heart of Oxwillow Nature Recovery is the Taylor family who have long-term roots in the Pymoor area of The Fens. The family has a deep knowledge of fenland and farming which has been passed down through the generations. Ross, Sarah-Jane and Craig Taylor are passionate about preserving nature and peatlands for the next generation and set up Oxwillow as the environmental arm of Taylor Farms, named after the ancient Oxwillow Loade which historically ran through their land. Their farm has an average peat depth of 35-60 cm with peat holes of over a metre in depth and buried layers of peat below the clay subsoil with organic matter contents ranging from 17-51%. So far Oxwillow has plans to establish 40 ha of grassland and ponds with the desire to create functioning wetlands, as biodiversity net gain units, and are engaging with partners at the landscape scale to help drive collaborative change. They also have the ambition to grow biomass crops with a raised water table and to reintroduce heritage crop varieties to areas of peat on their farm which they are unable to rewet.

Ross Taylor has developed the Oxwillow Biodiversity Recovery project

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Jo Bellett

Supporting and developing paludiculture in the UK

Elizabeth Stockdale – see page 4.

Jo Bellett was Technical Project Officer (November 2022 - August 2023) for the Paludiculture Engagement work at NIAB.

Paludiculture, or farming with high water tables, is a system of agriculture for the profitable production of wetland crops under conditions that support the competitive advantage of these crops. In the context of lowland peat soils, it is most usually achieved through raising the water table to achieve wetland conditions. While the term 'paludiculture' is a recent one, its practice in England goes back generations.

The aim of paludiculture systems is to combine the harvest of wetland crops for food, fodder, fibre and fuel with the provision of vital ecosystem services. This differentiates paludiculture from conventional rice paddy systems where environmental management is an add-on rather than an integral part of the system design. The term paludiculture was coined by researchers in Germany to provide a descriptive name that could be used across a range of productive systems that provide a sustainable alternative to drainage-based agriculture in peatlands. Paludi comes from the Latin *palus* meaning 'swamp, morass' and is linked to '*cultura*' meaning growing or cultivation to highlight the active management of these systems to deliver multiple outcomes.

Peatlands used for paludiculture seek to maintain the average groundwater level in the growing season around 20 cm below the soil surface or higher, and the minimum groundwater level is never more than 40 cm below the soil surface. This creates peat preserving conditions, but unless there are significant organic material inputs, peat generation will not occur. Paludiculture systems may also be used to strip nutrients from surface waters and reduce wind erosion. This concept provides production opportunities for the necessary, fundamental change in land use of drained peatlands to a more sustainable, wetter land use, which should benefit both the regional economy and the climate.

The Greifswald Mire Centre, in Germany, was established as a science-policy interface to support the restoration and sustainable management of peatlands and has pioneered the development of new paludiculture systems. In Germany and The Netherlands there are pilot sites with harvestable sphagnum lawns, reed and typha (bullrush) plantations, where the crop biomass is harvested as fuel

or to provide fibre for construction, as well as wet meadows with grass species adapted to a higher soil moisture content used as pastures, e.g. by light dairy cows or water buffaloes.

The identification of crops for wet peatlands is essential for the implementation of paludiculture. The Database of Potential Paludiculture Plants (DPPP) gives a global overview of conceivable paludiculture plants and their uses. Each 'Plant Portrait' collates information on plant characteristics and morphology, distribution and natural habitats, modes of cultivation and propagation and utilisation options. To assess the paludiculture-potential of plants the DPPP defines four levels of suitability based on three criteria: preservation of peat soil, market potential and existing implementation. Preservation of peat soil is the primary concern of paludiculture. In parallel, the UK Paludiculture Live list contains 88 native species with promising potential for paludiculture in the UK. The greatest potential for paludiculture is currently in the areas of fibre and biomass crops for construction, energy and a range of bio-

Thatching reed

Can this traditional material support new sustainable solutions? For many centuries, reed and sedge cutting was a vital part of the local economy in villages and towns across the UK. Evidence of the use of water reeds for thatching has been found dating back to the Bronze Age at Flag Fen near Peterborough. Reed from well managed reed beds in the UK is of high quality providing materials that master thatchers can craft into roofs that last for 25-50 years. A single thatched cottage roof of 150 m^2 has been estimated to store c. 6 tonnes of CO_2-eq; roughly equivalent to the emissions from 36,600 miles driven in the cottage owner's petrol car.

Architects are increasingly integrating thatch into new buildings and Norfolk reed is still highly prized by thatchers; the recent repair and re-thatching of the Globe Theatre sourced all the thatching reed required from Norfolk. However, cheaper reed imports (from Turkey, Hungary and more recently from China) have displaced the use of UK reed over the last 50 years. It is currently estimated that less than 5% of thatching reed used in the UK is sourced from the UK.

A focus on biodiversity and conservation in recent decades also tended to reduce the proportion of reedbeds that are actively managed with reed harvesting. However it has now been recognised that management of reed beds for harvesting high quality reed is beneficial to biodiversity. Therefore, it has been recommended by the Broads Reeds and Sedge Cutters Association that management designs for newly established reed beds should integrate the harvest of thatching quality reed over at least half the area to support long-term sustainability.

Figure 1. Harvesting reeds for thatching (winter 2022/23) at Cley, Norfolk

industrial uses. Examples of the most likely crops for the UK are shown below.

Examples of paludiculture crops that have potential for use in the UK grouped by products/markets

- **Food**: bilberry, celery, cheese, cranberry, meat, nettle, sedge grains, sweet grass grains, watercress and water pepper
- **Herbal remedies, medicines and biomedical**: bilberry, bog myrtle, cranberry, comfrey, hemp agrimony, lady's smock, meadowsweet, round leaved sundew and Sphagnum moss
- **Flavourings**: bilberry, bog myrtle, meadowsweet, round leaved sundew, water mint and wild celery
- **Construction materials**: fibreboards – typha and reed, light weight aggregates – typha, and roofing (thatching) – reed
- **Furniture and decorative homewares**: alder, rush and willow
- **Bioenergy**: typha, reed and willow
- **Growing media**: Sphagnum moss
- **Fabrics**: typha seed heads (down replacement) and nettle
- **Industrial chemicals**: reed (silica) and Sphagnum moss.

Further research is needed to identify existing products that can be replaced by paludiculture crops, or processes where paludiculture crops could displace current feedstock and identify the scale of opportunity which may exist for paludiculture in these markets. It is also important to understand the potential for UK paludiculture crop production to be displaced by imports once markets are established for these crops.

More work is also needed to develop best practice agronomy and management guidance for paludiculture crops.

The Lowland Agricultural Peat Taskforce identified that paludiculture provides an effective way to farm and in the same field also reduce the current deterioration of drained lowland peat soils as part of the mosaic of integrated solutions and land-use

change needed in lowland peatlands. Its roadmap to commercially viable paludiculture has now been adopted by UK Government. The roadmap sets out a plan to make the widescale adoption of paludiculture a commercial reality over a 10-year timescale, starting from 2023, by developing the business cases for different crop and product combinations. By 2033, the aim is to have unlocked paludiculture as a new opportunity for some farmers, particularly those farming on marginal or low-lying land. Current soil carbon trading schemes are not suitable for use on peat soils and the existing Peatland Code was designed for restoration projects. However, as paludiculture pilots are implemented at wider scale, with generation of the underlying data to quantify the benefits of paludiculture in terms of greenhouse gas emissions, farmers may also be enabled to access a second stream of funding via carbon trading schemes in addition to sale of paludiculture products.

Within the Nature for Climate Fund, Natural England is delivering the Paludiculture Exploration Fund (PEF) for England. The PEF has funded 12 projects (2023-2025) across England focused on tackling the barriers to developing commercially viable paludiculture on lowland peat soils (see later section *Paludiculture Exploration Fund*). NIAB is working with Natural England to deliver co-ordination and wider engagement across the PEF. The aim is to build, and then facilitate engagement amongst, a paludiculture community of interest and action for lowland England, drawing together the best of knowledge and experience from academia, farmers and wider supply chains including purchasers, processors and manufacturers. The Paludiculture Community can be found at paludiculture.org.uk.

More funding is also being made available to address key barriers to paludiculture such as the costs and practical challenges of water management for rewetting in lowland peat landscapes.

These projects, together with existing work, such as the Great Fen National Lottery Heritage Fund Project Peatland Progress, will tackle barriers along the supply chain and address issues associated with a range of crops suitable for paludiculture. Overall, these projects will support practical initiatives that will help in the reduction of peat wastage and greenhouse gas emissions and drive us along the road to a future where paludiculture is an integrated part of the UK landscape.

Paludiculture Exploration Fund NATURAL ENGLAND

Paludiculture demonstrations in lowland peatland regions with information sharing between projects

Fibre Broads – led by The Broads Authority. The project aims to 'unlock paludiculture' through several outcomes. Through feasibility discussions with farmers, it will identify areas in the Broads most suited to wetland crops. In a strategic alliance it will promote and provide a demonstration of paludiculture fibre products in the region promoting paludiculture sourced materials in developing consumer and construction products and explore new market opportunities for paludiculture products.

Developing sustainable land use options on the Somerset Levels – led by Farming and Wildlife Advisory Group Southwest. The project aims to explore viable land use options across the Somerset Levels & Moors (SL&M), overcoming economic and cultural barriers to raising water levels across hydrological blocks of peat and exploring paludiculture to improve water quality, specifically by reducing phosphate pollution levels within protected sites.

Low impact willow growing as a paludiculture crop – led by Coates English Willow. The project aims to develop more efficient planting, with lower herbicide use, and improved harvesting practises for willow whilst protecting and preserving the peat on West Sedgemoor in the Somerset Levels. The overall aim is to develop a high value product to provide sustainability to farming businesses.

Mapping and identification of peatland suitable for paludiculture in the East Anglian Fens – led by Fenland SOIL Ltd. The project aims to work with farmers to map IDBs to create paludiculture opportunity maps. The project will also use hydrological modelling of the landscape to understand water table fluctuation along with CO_2 and CH_4 emissions.

OPENpeat – Opportunities for Paludiculture and Engagement in the North West – led by Manchester Metropolitan University. OPENpeat will sharing best practice from existing and emerging paludiculture trials in UK and EU through direct farmer engagement and promote peer to peer learning between farmers in the Lancashire Mosses lowland peat area. During the project period, activities including interviews and workshops will explore the willingness of farmers on lowland peat to experiment with paludiculture.

Typha production at scale – from field to market – led by Lancashire Wildlife Trust. The project aims to develop understanding of the economics, practical issues, and environmental uplift of commercial Typha growing at field scale. Many practical aspects of growing crops on wet soil conditions will be explored from sowing through to management and harvesting. Other food crops will be grown under wetter farming at trial scale to explore these opportunities.

Typha seed heads for textile production – led by Saltyco®. Saltyco has led development of the use of typha seed heads as a replacement for goosedown. This project aims to develop and scale up the process of seed separation for Saltyco's patented BioPuff product and to explore the potential to use these seeds as planting source for new crop establishment. In addition, new uses and products will be explored for the Typha seeds to add further value to this paludiculture crop. The project will be strongly linked to the Lancashire Wildlife Trust Typha demonstration.

Sphagnum Farming: the green alternative to peat – led by Micropropagation Services. The project will scale up the production of Sphagnum Farming to pilot field scale working in the Lancashire Mosses. The aim is to produce sustainable growing media to replace peat and support the English horticulture sector, whilst also supporting lowland peat farmers with this sustainable, profitable Sphagnum crop on rewetted peat. The project will create a commercially sustainable demonstration farm and overcome identified barriers throughout the supply chain.

The Paludiculture Innovation Project – led by Harper Adams University. The project aims to show how paludiculture can be integrated into landscapes with pockets of peat such as lowland Shropshire. A demonstration and research site will be established on the university site to develop knowledge around the cropping techniques including assessment of machinery requirements and opportunities.

Developing management systems and practices for paludiculture

Develop protocols & best working practices for the use of drones for seeding and crop maintenance in Paludiculture – led by AutoSpray Systems. The project aims to explore potential new areas of use for drones in paludiculture scenarios for a range of crop management tasks, as well as the use of drones to monitor crop health. The project will also explore the environmental impact of drone use.

Is there a benefit from biochar integration – led by UK Centre for Ecology & Hydrology. Biochar is a charcoal-like product following the pyrolysis of biomass feedstocks under low oxygen conditions. Being high in carbon (>70%) and relatively stable, it is viewed as a form of carbon capture but may also reduce N_2O emissions and deliver other agronomic benefits. The aim of this project is to quantify the impacts on productivity and environmental impacts of paludiculture with and without biochar integration.

Developing a business case for paludiculture opportunities – led by Vitagrass Farms Ltd. The overall goal and vision for this project is to identify the variety of barriers to paludiculture at farm scale, and then to develop a model business case. A small-scale trial site will also explore a recommended paludiculture option. The anticipated crop for trial is sphagnum with an end use being the future amateur gardening market as an alternative to peat in compost/growing media.

Ben Tea • benjamin.tea@niab.com

Alternatives to peat for horticulture

Ben Tea is a technical manager at NIAB, with six years experience of growing native and non-native crops in protected environments and 15 year background in wholesale nursery. As a BASIS and FACTS advisor he is responsible for providing agronomic advise across a host of commercial and grant funded trials both for NIAB and as a consultant. His specialist areas include bespoke irrigation design and set up, pest and disease management (IPM), protected environment specialist growing, crop nutrition and growing media. Ben also works in business development and chairs NIAB's plant health and biosecurity team.

Peat has long been a popular choice in horticulture due to its ability to retain water and nutrients, making it an ideal growing medium for plant growth. However, its extensive extraction and use has raised environmental concerns, prompting the search for sustainable alternatives. In recent years celebrity gardeners and influencers have campaigned to protect the peatland peat bogs, raising the public's awareness to the subject and consequently adding pressure to address these issues.

Some of the major issues with the extraction of peat include the release of large amounts of carbon dioxide to the atmosphere as greenhouse gases contributing to global warming and climate change, disruption of the ecosystems leading to loss of biodiversity and essential habitats and an increase in the risk of flooding and flow of water on the land.

In recent years there has been an adoption of peat reduced growing media mixes. However, Defra pushed harder and commissioned a consultation phase which originally indicated the use of peat would be banned completely by 2030. This has since been brought forward and current legislation states that the use of peat for retail use will be banned in 2024 and peat used for the professional market will be banned by 2026. There are some exemptions, for example specialised areas will have access to peat products until 2030.

To address these issues, the horticultural industry has been exploring a range of alternatives to peat (Figure 1), for example coir, a byproduct of coconut processing. Coir has emerged as a well-liked substitute, increasingly favoured due to its lightweight nature and effective water retention capabilities. Nonetheless, coir presents its own set of obstacles, particularly in convincing environmentally conscious individuals. Coir is sourced and transported by ship over long distances before being further shipped within the UK on lorries. As a result, there is a potential risk coir could face similar problems like peat.

Figure 1. Alternatives to peat, from right to left: Top – vermiculite, clay balls and perlite; Bottom – coir, peat-free, peat reduced with woodfibre

Wood fibre and bark-based substrates are also viable alternatives. These materials are often byproducts of the forestry industry and can provide adequate water retention and properties for good plant growth. Additionally, expanded clay pellets, perlite, and vermiculite are mineral-based options that can be mixed with other substrates to improve drainage by increasing the amount of air in a growing media mix.

Alternatives

The concept of using household and garden waste has been explored as an alternative. However, as noted by WRAP, in many instances the end material lacks consistency. There is no standardised method to process and/or store material at homeowner level or within local councils which adds layers of complexity in establishing uniform material.

It is also observed that any prior plant protection or herbicide products used in the homeowner's garden may still contain active ingredients. This has adverse effects on subsequent growing material and therefore can affect future growing quality. Often there are pH issues and high sodium chloride levels found in this type of material making it also difficult to grow plants.

Farming diversification presents a valuable opportunity to source alternative materials for peat-free growing media. These farm-based materials can be utilised to support sustainable alternatives. Sheep wool can be processed into a valuable resource; it provides good water retention, helps improve soil structure, and adds organic matter to the mix. Similarly, Alpaca fleece has hydrophobic properties making it a potential component of growing media. Its ability to repel moisture can help increase drainage and prevent waterlogging. Mixing both sheep and alpaca fleece has the potential to create bespoke mixes based on grower requirement, time of year and growing set up. Animal manure, when composted properly, can be a rich source of nutrients for plants. It adds organic matter, improves soil structure, and contributes to the overall health of the growing medium. Though it must be noted that the bi-products from livestock waste cannot be used in growing media where it is used in food production due to regulatory constraints.

Currently it seems that anything considered waste is being considered for growing media. The bulk material from anaerobic digestion has also been considered but, due to the processing needs and available quantities, this is unlikely to become a major component.

One of the major limiting factors to peat free, and what made peat so popular, is nutritional content. Aged peat is naturally low in nutrients making it a perfect starting material and, with its high cation exchange capacity (ability to hold/release nutrients), was able to hold and release nutrients. Some peat free materials can be high, to almost toxic levels, in nutrients and some materials can actually lock up nutrients meaning end-users need to add more fertiliser to compensate, resulting in additional cost and higher risks to the environment.

Biomass conversion

Biochar has also been considered as an alternative to peat for its environmental benefits; locking in carbon in the soil. It is a charcoal-like substance that is

Figure 2. Total volume (%) of ingredients used in growing media in retail sector between 2011-2021 (Growing media monitor report (HTA, AHDB, GMA, Defra), 2022)

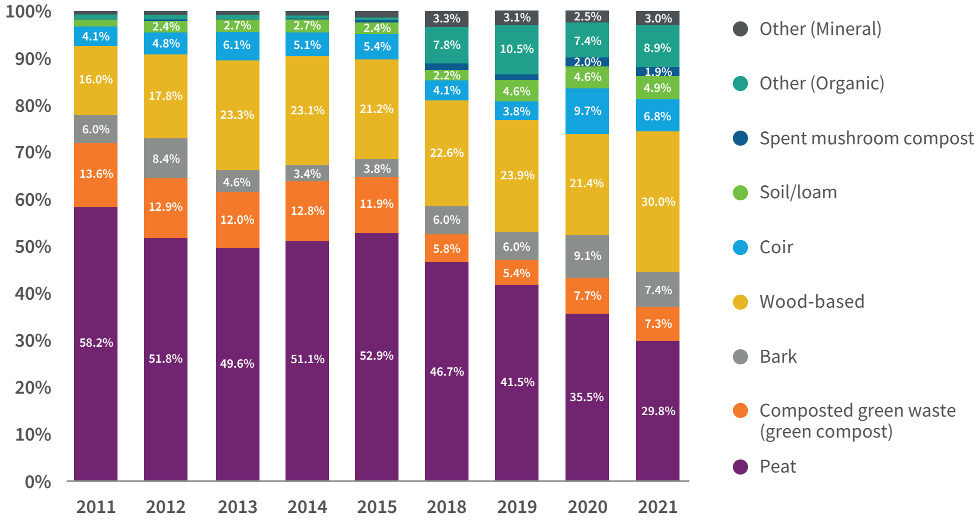
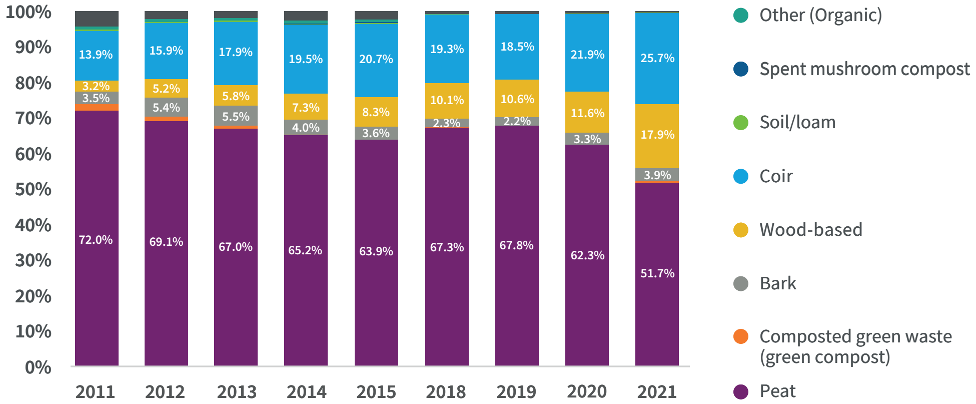


Figure 3. Proportion of professional growing media volume accounted for by different component (Growing media monitor report (HTA, AHDB, GMA, Defra), 2022)



produced through the controlled process of pyrolysis, which involves heating biomass (organic materials such as wood, agricultural residues, and other plant matter) in the absence of oxygen. This process results in the conversion of the biomass into a stable form of carbon-rich material with a highly porous structure.

The use of biochar can also provide a range of potential benefits in its application, including soil improvement, nutrient retention, pH regulation, water management, microbial activity and carbon capturing.

The need for peat free alternatives is not a new subject and the Horticultural Trade Association in conjunction with AHDB, Growing Media Association and Defra showed the overall proportion of ingredients in growing media between 2011-2021 across the retail sector and professional sector (Figure 2), both show

Figure 4. NIAB indoor seasonal glasshouse running spring trials looking at growing media formulations

a reduction in peat and increase in the use of these discussed alternatives (Figure 3).

The transition to peat free is not without challenges. Alternatives require adjustment to growing practices, including maintaining balanced nutrient levels. Water holding capacity and irrigation inputs can be harder to achieve. Peat alternatives tend to have a higher (alkaline) pH opposed to peat which is generally acidic. Nutrient uptake is pH dependant so being able to balance pH levels in peat free alternative fixes can prove difficult.

The horticulture industry is facing a concerning lag in knowledge exchange concerning peat-free alternative. Reasons include the winding down of AHDB Horticulture as research is no longer being disseminated down to the growers, as well as a much-needed increase in nursery trials into best growing practices, yet resistance to change exists. And finally, there is a considerable amount of dependency on growing media companies for agronomic information.

Supporting change

The UK has been particularly active in the adoption of peat free growing media in comparison to other EU countries. For a long time, the 'peat issue' was a UK problem and it was clear that other EU countries were not following the UK in banning peat. Fast forward five to ten years and, with the peat free movement on social media and Defra's move to finally set a date, the peat free issue is now being discussed on the continent.

In support of these changes, NIAB has been conducting growing media trials for several years, evaluating the different formulations and the performance of plant growth in these areas (Figure 4). The extensive glasshouse facilities at Cambridge and East Malling, in Kent, offer a range of specifications, presenting good commercial growing standards and offering controlled conditions and uniformity of environment. Trials can be established in basic heated areas or heated with supplementary lighting, as well as the option for outdoor hard standing areas fully equipped with automated drip or overhead irrigation (Figure 5). NIAB runs a range of trials looking at seed and cutting composts for propagation (Figure 6), indoor growing medias for house plants, general purpose and specialist growing medias for all bedding and hardy nursery stock plants.

Figure 5. NIAB outdoor trials area

Figure 6. Propagation trial evaluating the development of peat free seed and cutting compost

NIAB's Glasshouse Services

NIAB delivers trials across a wide range of crop and plant species with the equipment, experience, resource, and facilities to offer a complete custom-made package from trial design, trial delivery, data collection, analysis, and reporting to your specification. Trials can be carried out at Cambridge or East Malling, with site tours available.

www.niab.com/services/glasshouse

ghservices@niab.com

Further reading

Compost production for use in growing media – a good practice guide (WRAP)

Performance analysis of mixed food and garden waste collection schemes (WRAP)

Growing media monitor report (HTA, AHDB, GMA, Defra)

ARTIS

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16 January	**Best practice agronomy for cereals and oilseed rape** • Trained by Bryce Rham • NIAB HQ
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7 February	**Essentials of good soil management** • Trained by Nathan Morris • NIAB Park Farm
13 February	**Advanced nutrient management for combinable crops** • Trained by Stuart Knight • NIAB HQ
27 February	**Gross margin, budgeting and management** • Trained by Chris Winney • NIAB Park Farm
29 February	**Better control and avoidance of disease in cereals** • Trained by Aoife O'Driscoll • NIAB HQ
5 March	**Understanding potato crop growth stages (am)** • Trained by Sarah Roberts • NIAB HQ
	Measuring and monitoring potato crops for enhanced crop performance (pm) • Trained by Sarah Roberts • NIAB HQ
6 March	**Scheduling irrigation to optimise yield and quality in potatoes (am)** • Trained by Katharina Huntenburg • NIAB HQ
	Understanding and optimising potato nutrition (pm) • Trained by Elizabeth Stockdale • NIAB HQ

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Aoife O'Driscoll • aoife.odriscoll@niab.com

Pathology into practice – IPM for wheat diseases

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

Disease management in wheat continues to provide its challenges, with the 2023 season exacerbated in many cases by earlier drilling and extreme rainfall events, and a light being shone on the value of varietal resistance, which had a significant influence on the effectiveness of fungicide programmes. As farmers and agronomists begin to navigate the 2024 campaign, how can NIAB support them in making the best, evidence-based decisions? In this two part series we will take a snapshot look at just some of the knowledge and expertise from collaborative research projects and independent advice on disease management, which translates into on-farm practice. Part 1 focuses on foundational decisions made in the late summer and autumn; notably variety selection and cultural controls.

Start with the basics; variety choice

Traditionally, higher yielding wheat varieties have been those that produced the largest response to fungicides. But recent varieties are breaking the mould in that they yield well and offer strong disease resistance. When selecting the most suitable varieties for individual situations, we can look at the national picture from AHDB Recommended List data as well as local data from over 14 of NIAB's regional trial sites where we have a long run of records showing how disease has affected yield and how varieties respond to fungicides. This is supported by our summer Open Days and popular stand at the annual Cereals Event where we showcase the latest varieties coming through for recommendation, as well as weekly harvest updates during the late summer period.

At a more fundamental level however, the battle against changes in pathogen virulence and fungicide sensitivity continues. Part 2 of this series will focus on new tools in development to monitor and predict these changes rapidly, efficiently and more cost-effectively than ever before. In the medium to long-term however, newly-funded collaborations with industry and academia look to further exploit crop genetic resistance and emphasise NIAB's commitment to co-development of new varieties as a long-term, strategic priority.

Figure 1. The power of drilling date. Mid-September sown wheat varieties on the left, and early September sown varieties on the right

Exploiting genetic resistance

The Yellowhammer project, funded by BBSRC and AHDB in collaboration with seven European breeding companies, has trialled over 400 varieties at breeder sites across northern Europe and generated an extensive genetic data set which can be linked to variety field performance. These ambitious Genotype x Environment studies allow us to understand how best to combine adult plant resistance genes for durable resistance to yellow rust. In the future, we will also see a greater shift towards growing hybrid wheat varieties with improved yields and environmental stability.

NIAB has developed synthetic hexaploid wheat (SHW) lines by crossing durum wheat with wild goatgrasses as a core resource in diversifying available germplasm for future varieties. SHWs and derived pre-breeding lines are being screened in projects searching for new sources of genetic resistance to key wheat diseases, including Septoria, with trials conducted at NIAB sites that act as hotspots for this disease, particularly Devon and Cornwall. Some of this screening work is NIAB's contribution to the five-year BBSRC Delivering Sustainable Wheat (DSW) strategic programme, led by the John Innes Centre in partnership with multiple research institutes and universities. DSW follows on from previous large collaborations such as

The Wheat Improvement Strategic Improvement Programme (WISP) and Designing Future Wheat (DFW); both of which made considerable advances in generating new wheat germplasm with the next generation of key traits. NIAB's involvement in DSW is further complemented by a BBSRC PhD project, in collaboration with The Morley Agricultural Foundation and Nottingham University, which will focus on novel sources of Septoria resistance derived from NIAB SHWs.

A conundrum that plant breeding has regularly faced is breeding for durable resistance. Screening for and taking varieties through to registration, with the right set of disease resistance genes against pathogen populations which can rapidly evolve and overcome these genes, is a risky process. To address this, breeding programmes are beginning to exploit developments in high throughput diagnostic tools which use fungal gene diversity information to predict pathogen virulence or avirulence against breeding material with specific resistance gene combinations. NIAB is leading and collaborating on two projects seeking to investigate these avirulence genes in rust pathogens affecting wheat, barley and oat and Septoria in wheat. In the long term, both projects will enhance rust and Septoria surveillance capacities in the UK and internationally, and facilitate risk assessments for disease resistance breakdown. Both projects are again, generously supported and funded by the BBSRC.

Lay the foundations; drill wisely

A five-year study into how crop management decisions influence the development of Septoria and subsequent impact on yield and fungicide response can provide much guidance on this. The study, led by ADAS in partnership with NIAB, SRUC, Teagasc and UCD, and funded by AHDB and BASF, looked at factors including sowing date, variety, seed rate and fungicide input across 25 sites in the UK and Ireland. A key finding was that sowing date affected disease pressure (especially early in the season) and response to fungicide (compared to untreated). Early sowing (mid-September) was predicted to decrease effective varietal Septoria resistance ratings by 0.6 (compared to an early October sowing date), whereas later sowing (mid-late October) was predicted to increase effective resistance ratings by 0.6, for the range of varietal resistance ratings tested (4-7). By sowing varieties with stronger disease resistance later in the autumn, there may be considerable scope to reduce the risk of a damaging Septoria epidemic.

Turning science into practice

NIAB's *Variety Interactions* and *Agronomy Strategy 1* publications, available to the NIAB Agronomy Membership, are just two examples of hard copy resources that combine knowledge on the latest research from the lab and field to help our members make informed early autumn decisions for winter cereals. Like all four of the NIAB Agronomy Strategy documents, it is designed to provide detailed, independent agronomic guidance across the nation, which can be refined for specific farms and circumstances. The Strategy's are augmented by our in-season weekly agronomy e-newsletters, member technical events plus access to crop technical specialists and your local NIAB agronomist.

In the spring 2024 issue of *Landmark* we will focus on spring decision making, surveillance and monitoring of pathogens and how this data feeds into fungicide programme planning.

Figure 2. Untreated wheat varieties in Devon succumbed to the challenging Septoria pressures of 2023

Figure 3. An untreated SHW line, showing strong genetic resistance to high disease pressure in NIAB trials in Cornwall

Figure 4. SHW lines trialled alongside commercially available wheat varieties

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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.

Elizabeth Stockdale – see page 4.

Long-term value in long-term experiments

It is difficult to quantify the exact number of long-term experiments (LTE) globally; in 2003 there was estimated to be around 600 field experiments over 10 years old but the figure is likely to be higher today. A useful resource documenting the details of these LTEs is GLTEN, (glten.org) a network of global long-term experiments across six continents which includes the majority of those found in the UK.

UK agriculture is lucky to have a rich resource of long-term experiments. There are thought to be 25 experiments worldwide greater than 120 years old; 11 of them are in the UK. NIAB delivers several LTE on behalf of The Morley Agricultural Foundation (TMAF) investigating rotations, cultivations, fungicide response, soil amendments and mineral fertilisers (Figure 1). The oldest of these, the Saxmundham Experimental Site was set up in 1899 and is regarded as the third oldest continuing agricultural experiment in the country.

In June 2023 Rothamsted Research hosted the Association of Applied Biologists (AAB) conference '*Long-term experiments: meeting future challenges*', on the 180th anniversary of the Broadbalk winter wheat experiment, the world's longest running field trial. The conference emphasised the importance of LTE in tackling the problems and questions of 21st century agricultural systems. Nathan Morris and David Clarke attended the conference and presented long-term findings from some of the TMAF-supported long-term experiments, managed by NIAB, which are used regularly to explore the challenges farms face today.

Figure 1. Long term experiments supported by the Morley Agricultural Foundation (TMAF) delivered by NIAB investigating rotations, cultivations, fungicide response, soil amendments and mineral fertilisers

Experiment	Start date	Funders	Location
New Farming Systems Cultivations	2007	TMAF, JC Mann Trust	Morley, Norfolk
The Manure and Organic Replacement (MORE)	2011	TMAF	Morley, Norfolk
New Farming Systems Rotations	2007	TMAF	Morley, Norfolk
Sustainable Trial in Arable Rotations (STAR)	2005	TMAF, Felix Thornley Cobbold trust	Otley, Suffolk
The Saxmundham experimental site: Rotation I	1899	TMAF	Saxmundham, Suffolk
Morley fungicide response winter wheat and winter barley	1986/2002	TMAF	Morley, Norfolk
Periodic lift in sugar beet	1997	TMAF	Morley, Norfolk
The Morley Soil and Agronomic Monitoring Study (SAMS)	2018	TMAF	Morley, Norfolk

Adapting long-term experiments to meet current and future challenges

The Saxmundham experiment's primary goal was to investigate and compare crop and soil response to mineral phosphorus and potassium fertilisers, which in 1899 were relatively modern technologies, compared with the traditional approach of regular applications of farmyard manure (FYM). These original plots are still in place. Over the past 120 years Saxmundham has been fundamental in developing an understanding of phosphorus in managing soil fertility and crop nutrition and has shaped many of the management guidelines used today.

However, as is to be expected with experiments that span decades and, in the case of Saxmundham centuries, some treatments become dated, lose relevance and require updating. Soil analysis showed that two treatments that had not received any P or amendment additions for a number of decades, bonemeal (not applied since 1990s), and the N only plots had similar soil indices to the untreated. These plots therefore provided a platform to test new modern P management techniques.

In autumn 2018, two new treatments were introduced. Foliar applied P fertilisers have the potential to reduce dependence on soil applied P. The historic N only treatments now receive repeated applications (up to four per season) of a foliar phosphorus fertiliser (Folex P) along with mineral K fertiliser to quantify how much of a crop's P demand can be met through foliar applications. The plots historically receiving bonemeal now receive annual additions of green waste compost (typically 18 t/ha) to match the organic matter additions applied in the FYM plots (FYM applied at 25 t/ha). Compost has a lower P content than FYM therefore NIAB is investigating whether by increasing soil organic matter soil structural properties can be improved and soil P indices can be managed at lower levels where improved rooting and plant-soil interactions improve P uptake.

Testing innovative ideas on existing platforms

The fundamental treatments of a long-term experiment may not necessarily need to change to provide answers to new questions. Modern technologies and measurement techniques can be employed to give new understanding to the interactions arising from the underlying historic management techniques. For example, recently PhD projects have used techniques such as root length colonisation measurement techniques to distinguish distinct levels and communities of arbuscular mycorrhizal colonisations from the use of cover crops in the New Farming Systems rotations experiment. Another project used X-ray computed tomography to show differences in pore composition between the rotational systems at the Sustainable Trial in Arable Rotations (STAR) trial.

LTE can also be used to test new hypotheses by building on the treatments and long-term effects of these already in place. In autumn 2023 the 24m x 36m plots on the NFS cultivations experiment will be split into to 16 smaller plots growing novel and conventional wheat lines with current optimal or a reduced N rate, on top of the respective underlying historic cultivation treatment. The aim is to identify lines that are best suited to regenerative agriculture practices such as reduced cultivation intensity and lower synthetic nitrogen inputs, with the data from the conventional varieties under optimal N still contributing to original project aim and dataset.

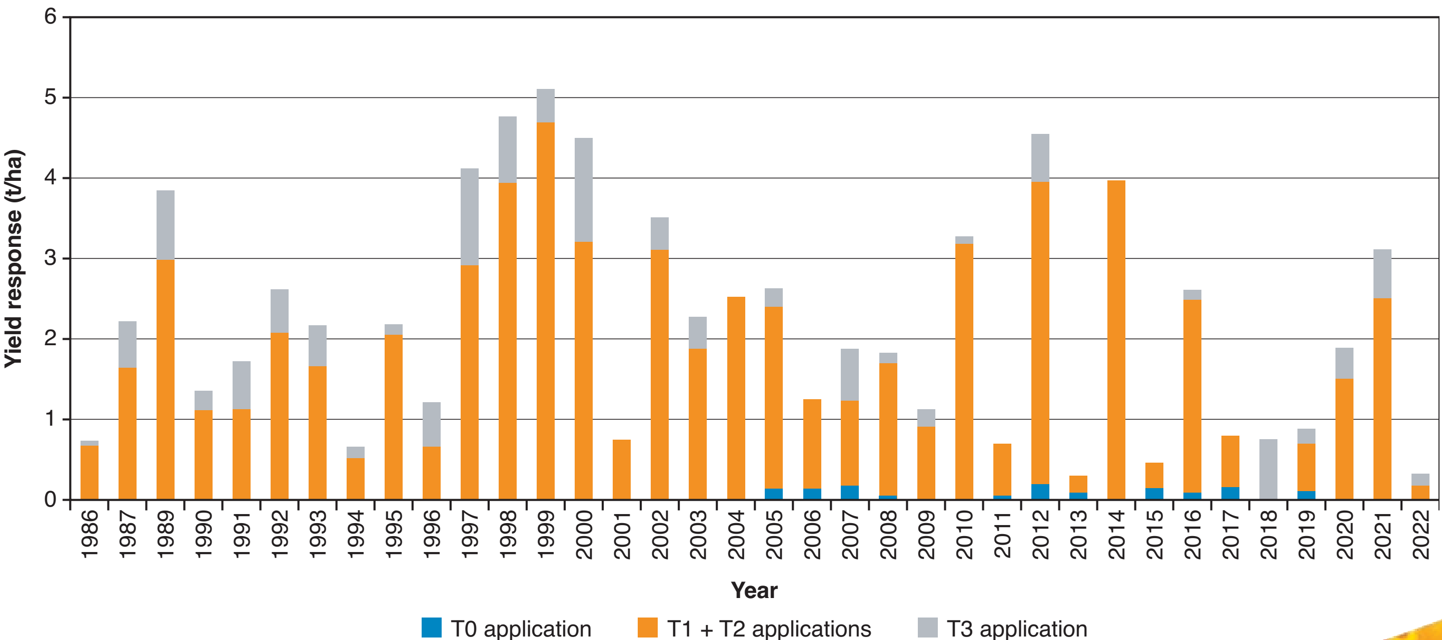
Long-term experiments for monitoring system change

It is said that you cannot change the direction of the wind, but you can adjust your sails to reach a destination. In the case of climate change the 'wind' is literally changing and as the effects of climate change impact our production systems, long-term experiments are critical for understanding how our cropping systems, soils and environment are responding and what interventions (how to adjust our sails to flog the metaphor further) can enhance our resilience.

The Morley winter wheat fungicide response trial (Figure 2) has been running since 1986 and provides an annual appraisal of disease pressure and fungicide performance for the area. Since 2005 an application at T0, or Growth Stage 30, timing has been included. However, response has historically been relatively small. With climate change it is expected that autumn and winters will become warmer and wetter across the region, meaning conditions might become more conducive for disease development. However, the value of the T0 timing has yet to be seen, although we can see how the yield response to fungicide strategies varies significantly by season.

Additionally, these experiments can provide an opportunity monitor how modern technologies and changes in

Figure 2. Yield responses of winter wheat (typical farm varieties selected for moderate disease resistance) to fungicide programmes at Morley



legislation impact production compared to a historic baseline. In the winter wheat fungicide response trial, NIAB has been observing the impact of changes in chemistry (and loss of active ingredients, such as of chlorothalonil). In the future, we may be able to see how modern technologies such as gene editing compare to historical controls.

New long-term experiments

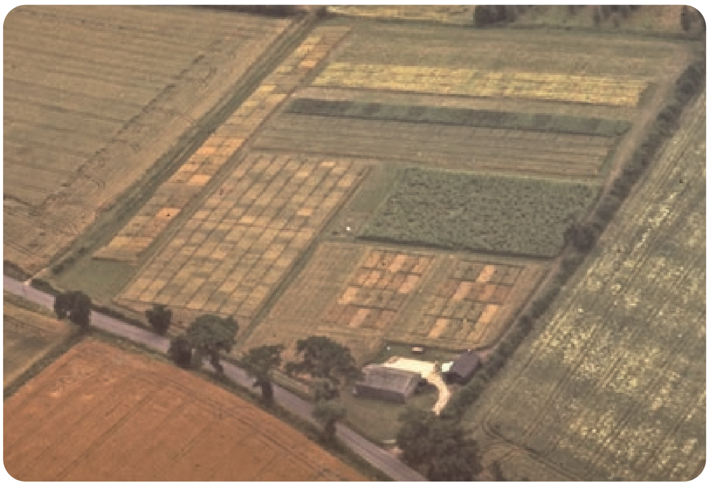
Historically long-term agricultural experiments have often been designed to test the effects of a specific treatment or factorial combination of treatments, such as fertiliser/manure rate or type on soil and crop properties. These experimental designs make it difficult to study impacts on chosen metrics where the whole system has changed. This was recognised in the design of a new long term field experiment at Rothamsted Research (Large-Scale Rotation Experiment). Instead, this new design enables comparison between farming systems that differ in terms of multiple interactive management practices, including rotation diversity, cultivation regime and amendment use. This will allow for better understanding of how a system meets challenges relevant to modern agriculture such as achieving carbon neutrality or farming free of pesticides. However, due to the complex number of factors that are modified in each system, a traditional replicated block experiment was economically and spatially impractical and the field trial design required adaption building on advances in statistical analysis and data exploration.

The Morley Soil and Agronomic Monitoring Study (SAMS) is a new type of long-term study monitoring datasets of actual farm practice alongside the long-term plot-based studies at Morley. Although not strictly an experiment that tests different treatments it fills a critical gap in the chain linking research and its application. The study consists of 30 representative monitoring sites across Morley Farms (including sites with high, low and unstable yields as well as three headland sites and one long-term grass site) that were identified using yield map analysis techniques. Morley SAMS aims to provide a long-term record of how modern agricultural best practice implemented in a conventional arable system impacts soil health and crop productivity over time. A set of annual and rotational soil and crop measurements record the variation in both soil properties and crop performance through space and time. The dataset is now five years old and is already yielding insights into the variation and driving factors of organic matter differences between and within fields, together with the impacts of soil organic matter on crop response to inputs.

Long-term results

Annual reports for the Saxmundham, winter wheat and barley fungicide response and STAR experiments can be found on the NIAB Agronomy Membership website and the TMAF website. All these experiments would not be possible without the help and enthusiasm of the host farmers who carry out many of the treatment operations.

Figure 3. Saxmundham site through the years



1978

Circa 1980

1986

2023

Historic photos: Edmund Brown

Margaret Wallace • margaret.wallace@niab.com

New technology in DUS testing

Dr Margaret Wallace is one of the leads in the team delivering DUS testing and seed certification at NIAB. She has 18 years' experience as a DUS examiner, starting at AFBI Crossnacreevy before joining NIAB in 2013. Her expertise means she is well placed in representing UK interests in UPOV Technical Working Parties on Agricultural Crops and the recently formed Testing Methods and Techniques.

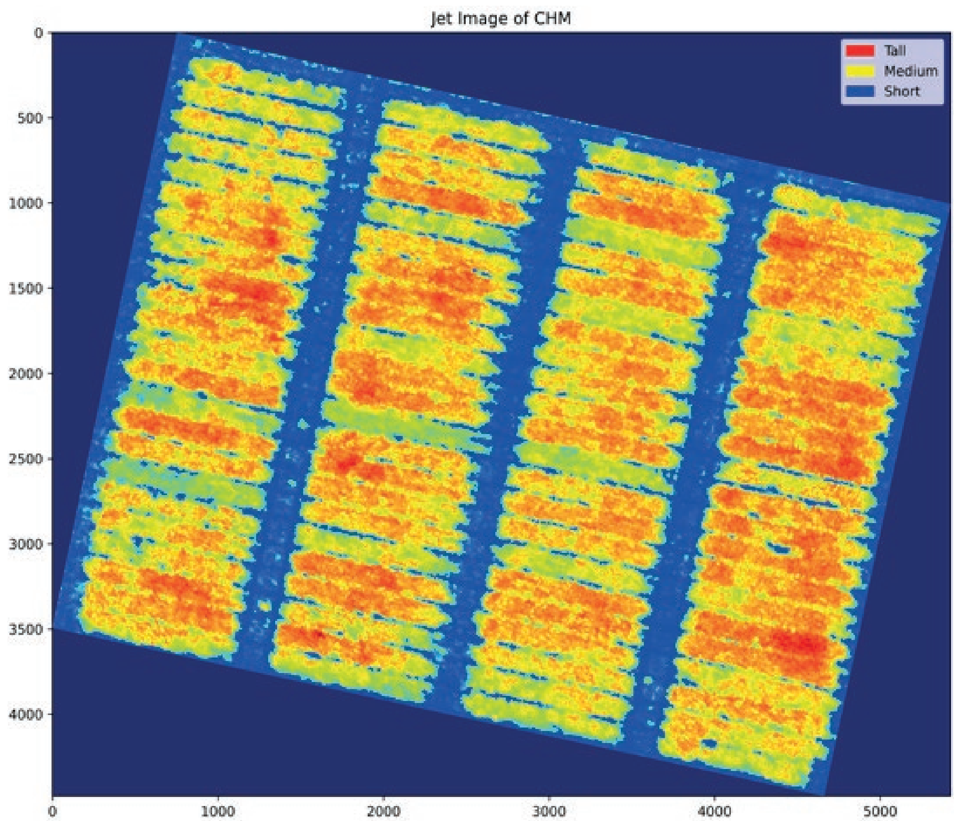
Distinctness, Uniformity and Stability (DUS) testing is used to award Plant Breeder's Rights and in the process for Variety Listing. PBR allows breeders to claim royalties on the sale of seed or plant material of a variety. Variety Listing (formerly National Listing) is required in the UK (and other countries) to legally market some agricultural crops and often involves a separate VCU (Value for Cultivation and Use) test.

The DUS test has been a part of UK agriculture for many years; the UK was one of the founding members of the inter-governmental organisation UPOV, the International Union for the Protection of New Varieties of Plants, which aims to harmonise testing across its member countries. The royalties claimed by a breeder provide a return on the substantial investment that has gone into the development of that new variety. In the UK, the Variety List is a requirement for seed certification.

The testing process confirms if a new variety is clearly different from all other known varieties based on a characteristic set that should be consistent across growing cycles. Uniformity is a measure of how different the plants look within the variety. The level of uniformity required is set by the method of production, for example a barley variety, produced by self-pollination, is expected to be more uniform than a cross-pollinated oilseed rape variety. Stability is usually inferred by uniformity.

The distinctness criteria require each new variety to be compared with all varieties in common knowledge. This means that the reference collections can be immense – think how many wheat varieties there are in the world. The test centres use many criteria to rule out varieties that are not similar so that only the most relevant are included in a growing trial. However, for the major agricultural crops, this still means a large number of field plots are needed. Test centres across the globe are investigating new methods to incorporate into systems to allow them to keep up with the high numbers of applications received each year; the UK is no exception.

Figure 1. Using drone imaging in assessing height in DUS trials



DNA technologies

DNA profiling cannot entirely replace phenotyping in a DUS test. Two varieties that look different may have the same DNA profile. This means that although they look different, they would be considered the same. The other issue is the definition of "distinct". How different would a profile need to be if it were to be considered clearly distinct and would the difference need to be in a region of the genome that is coding, ie would it need to be linked to a trait? If the difference is in an area of the genome that is non-coding, then this could make registering a new variety quite simple without any genetic gain or benefit to the end user. So, a totally DNA-based DUS test is not appropriate (yet…we do not know what the future holds) but the use of genetic information is becoming more prevalent in current DUS systems.

There are two internationally recognised methods for the use of marker information during a DUS examination. The first replaces the traditional assessment of a characteristic with a marker. This assumes a reliable link between the marker and the trait and is most efficient where a separate test or trial is required to observe the characteristic. The other method is using genetic data to screen the large variety lists (reference collections) to identify the most similar varieties, which are then grown in the trial. This along with the many other types of screening, e.g. comparison of data or variety descriptions, review of photographs, expert opinion (known as walking reference collection), can be very effective in reducing trial size and allow better trial design, potentially resulting in faster, cheaper DUS tests.

The national authorities of the UK are committed to exploring the use of molecular markers in DUS testing systems. NIAB is conducting two studies with the potential to implement molecular markers in DUS testing funded by Defra. The first, and larger of the two, is screening a significant portion of the barley reference collection. This study will initially explore the marker information to establish the relationship between the varieties (genetic distances) but will also identify any new trait-specific markers. The work builds on previous studies in barley genetics and will potentially go some way to resolve a growing issue, particularly with spring barley, where genetic gains are not showing clearly in the phenotype of the varieties. The goal is to identify very similar varieties earlier in the testing process to give more opportunity for assessment without elongating the testing period or dramatically increasing the costs. Spring barley is an important crop in the UK, not just for the whisky drinkers, so it is important that the testing system is relevant and effective.

The second project again builds on NIAB's expertise, this time in soft fruit genetics, specifically raspberries. Although smaller in funds, the ambition of the project is no less bold. The first task is to develop a set of markers that are robust, reliable and will be somewhat future-proof. Exome capture sequencing and whole genome sequencing will be used to produce the data and give a view of the best method for future implementation. The data will then be analysed using similar strategies as the barley project with the addition of data augmentation and machine learning.

There are two EU Horizon-2020 projects heading towards their final year, both focused on improving varietal testing (DUS and VCU). NIAB is working within the INVITE project (h2020-invite.eu) to develop a set of markers to assist in the selection of most similar varieties from the wheat reference collection. As with the barley project, the aim is to be able to screen the collection earlier in the process and grow a smaller set of varieties in the trials. NIAB will also work with Biomathematics and Statistics Scotland (BioSS) to assess new ideas for using genetic data to reduce trial sizes further. The molecular work is one of eight work packages and wheat is one of ten crops within the project. The UK is also involved in the InnoVar (h2020innovar.eu), which is being co-ordinated by the Agri-Food and Biosciences Institute (AFBI). This consortium has focused primarily on wheat and the project also has a strong emphasis on the use of genetic information.

To suit the out-crossing nature of oilseed rape, the DUS test is based on large amounts of measured data. The collection of approximately two million data points is intense, with the majority being collected between flowering and pod development. NIAB, funded by the EU's Community Plant Variety Office (CPVO) and the UK's Animal and Plant Health Agency (APHA), were involved in a project with the French company BioGeves to scope the use of markers in oilseed rape DUS testing. The end goal is to find a marker set and a process that could effectively screen

Figure 2. Winter cereal DUS trials at NIAB Park Farm on the outskirts of Cambridge

invite

The INVITE project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 817970

INNOVAR

THIS PROJECT HAS RECEIVED FUNDING FROM THE **EUROPEAN UNION' HORIZON 2020 RESEARCH AND INNOVATION PROGRAMME** UNDER GRANT AGREEMENT N. 818144

the reference collection to reduce the number of varieties grown each year. The initial project showed that bulking seeds before extracting DNA was a useful method and identified some markers. The second project (NIAB was an observer partner due to Brexit) consolidated the marker set and genotyped a larger subset of the reference collection.

The potential third project will be to establish a method of implementation. One of the main issues to overcome is the timing of data. The time between the closing date for applications and drilling the plots is very short. The majority of the planning and preparation is carried out before the applications have arrived. Postponing this until genotype data has been analysed is inconceivable, therefore a full review is required.

NIAB also conducted a short study of the genetic distances within the field bean reference collection. The marker set had been developed during other research work, so it was relatively simple to conduct the study which had some good outcomes. A proposal for further work will be submitted soon.

Drone imaging

Unmanned Aerial Vehicles (UAV) are everywhere these days, with varying degrees of acceptance. Rules surrounding where and when they can be flown can reduce their use in trial work. Weather conditions also dictate flights or effectiveness in image collection. However, in collaboration with NIAB's data sciences team, the DUS examiners have been imaging trials for four growing seasons and are achieving a good correlation with the measurements taken by hand. The focus has been on height measurements as it is likely to be the most beneficial. To be able to use images collected by UAV and calculate the height of a plant would significantly reduce staff time and cost even though it is only one characteristic. Once the technique is honed to ensure consistent results, a review of the test protocols is likely to be required. Currently, in the crops tested at NIAB, the protocols require plant length to be observed. This involves straightening the plant and any branches to take account of the full length of the plant. The images are capturing plant height – the top of the natural canopy or the highest point before the plant droops. There is still work to be done before implementation, but the technique is promising.

The INVITE and InnoVar projects both have an element of image capture and data analysis. The InnoVar work has been using UAVs and results are similar to the findings coming from NIAB. The two studies have been established independently, which shows that the results are not dependent on any one system, which should make the technology more palatable to policymakers.

The INVITE project has focussed initially on stand-mounted or hand-held imaging with mobile phone cameras, using tomatoes as the test subject. Early versions of the software had some user platform issues. An update has recently been circulated between the partners, so when we have finished our normal autumn work, we will be off to the farmers market to try it out.

Figure 3. Winter oilseed rape DUS trials at NIAB Park Farm on the outskirts of Cambridge

Developments in the existing elements

It is not all about new technologies. The DUS test centres are always reviewing the usefulness of the phenotypic characteristics listed in the protocols, considering new characteristics or analysis techniques. Recently, the Plant Varieties and Seeds (PVSC) and National Lists and Seeds Committees (NLSC), which make decisions on PBR and Variety Listing, have approved the introduction of pro-anthocyanidin as a special test in the barley protocol and other new phenotypic characters are on the agenda for discussion.

The UK's Inter-Departmental Statisticians Group (IDSG) has been reviewing the Combined Over Years Uniformity, or COYU, analysis. The final investigations before implementation of the COYU-Splines method in the UK are underway. This is not intended to change the uniformity criteria, but instead introduce a more effective calculation method.

The methods used for statistical analysis are also being considered in the INVITE project. BioSS and NIAB statisticians are playing an important role in linking the academic research with the practical DUS testing methods. Their expertise in UPOV principles is key to the success of the studies for future implementation.

The research groups are very active in exploring potential developments in DUS testing, using expertise across a range of subjects. However, if you think we are missing something or have suggestions for what else to investigate, please contact the DUS team.

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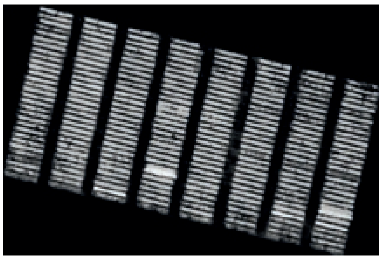
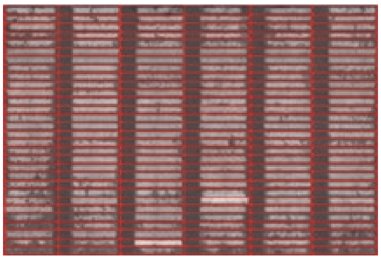
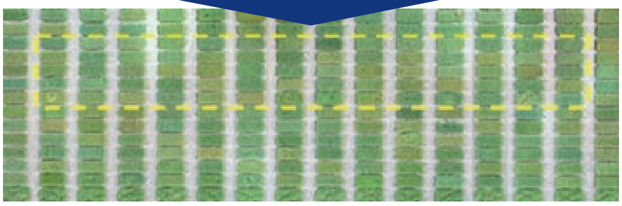


Canopy height model (CHM)

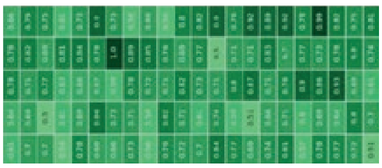


Automated plot segmentation

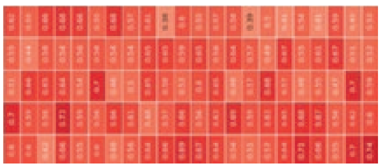
PLOT-LEVEL ANALYSIS



Field-level orthomosaic



Vegetation index



Yield estimation

NIAB's offering:

- Field overview images
- Establishment counts
- Ear counts
- Plant performance and health
- Vegetation Indices
- Dynamic Crop Growth (Minimum five flights)
- Other analysis available on request

NIAB

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Novel approaches to controlling apple canker

NIAB's Matevz Papp-Rupar and Scott Raffle describe the latest research on apple canker, which is hoped to reduce the severe impact of the disease.

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

Dr Matevz Papp-Rupar is a research leader in the pest and pathogen ecology department in East Malling with over 10 years' experience in plant pathology. His focus is on the development of sustainable, ecological approaches for control of plant pathogens and improving resource use efficiency in horticulture.

Apple canker caused by the pathogen *Neonectria ditissima* (Figure 1) continues to give rise to 10-20% tree losses per year in young orchards in the early years after establishment, and it is still considered one of the highest priorities for research by UK apple growers.

This new Growing Kent & Medway funded project is exploring novel approaches such as biocontrol, alternative spray programmes, and soil amendments for improved tree health and resilience with the hope of improving canker management practices.

Collaborating with industry partners Agrovista and Avalon Fresh, the work has been split into three separate objectives, one examining ways of reducing stress at planting time and improving tree establishment, the second seeking ways to increase the quantity of beneficial mycorrhizal fungi in established orchards, and the third assessing novel spray products for control of apple canker at leaf fall.

In work to improve tree establishment, NIAB is experimenting with six newly planted commercial Gala orchards, some planted on sites prone to drought and some on sites prone to waterlogging. Commercial evidence suggests that Gala orchards experiencing such extreme conditions brought about by climate change, are at greater risk of canker development. The project is seeking to use microbial soil amendments at planting time to improve tree growth and productivity. Commercial mycorrhiza and Trichoderma-based products have been applied to each orchard either alone or in combination. The mycorrhiza was sprinkled on the tree roots before planting, while a Trichoderma suspension was used as a pre-planting root dip. During the life of the project, canker incidence, tree mortality and tree growth (measuring girth) will be recorded every six months to compare the treatments.

Research in established orchards is seeking to find ways of increasing natural populations of mycorrhizal fungi. In an assessment of soils in four commercial established orchards, no natural mycorrhizal species were found, but researchers have demonstrated that their presence can improve soil drainage, soil health and nutrient uptake by the tree, which will enhance tree health, tree growth and the ability to withstand pathogen infection.

Wildflowers are known to support the growth of naturally occurring and introduced mycorrhiza, so NIAB is experimenting with wildflowers inoculated with mycorrhiza, which are being sown in tree alleys (Figure 2), in the hope that the mycorrhiza will spread into the established tree row. Previous NIAB research has identified the optimum species of wildflower to use for attracting pollinators and beneficial insects into orchard crops. A selection of those was also shown to be compatible

Figure 1. Typical canker damage causing death to apple tree

with mycorrhizal fungi and could provide improved soil performance and increased beneficial insect populations. Additional work is examining the use of Agrovista's modified root pruner, which dispenses mycorrhizal inoculum directly to the tree roots during the root pruning operation. Presence and populations of mycorrhiza will be recorded at both the beginning and the end of the project.

In researching alternative control agents, a wide range of substances are being assessed in a newly planted orchard which is being artificially infected by *Neonectria ditissima*. Products authorised for use in the UK but not currently on apple are included, along with biocontrol products with antimicrobial properties, which are being applied both with and without biostimulants and defence elicitors. Examples of novel products being assessed include a food preservative that is systemic and has performed well in China, and a species of yeast which offers a protective shield to exposed wood and outcompetes other naturally occurring organisms.

Figure 2. Wild flower strips have been established in orchards to enhance mycorrhizal populations

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Progress towards forest bug control

NIAB's Francis Wamonje and Scott Raffle outline how a research project is developing new knowledge to improve its management in orchards.

Since the withdrawal of the broad-spectrum insecticide chlorpyrifos in 2016, growers and agronomists have been finding increasing numbers of new insect pests in apple and pear that had previously been controlled. In some cases, insects that had not been considered as pests for a generation or more of fruit growers, have gradually been reappearing. The forest bug (*Pentatoma rufipes*) is one such pest.

Like many other shield bug species, such as brown marmorated stink bug, forest bugs produce a sticky defensive secretion with a strong smell which can contaminate fruits such as raspberry and cherry, but the bug is considered to be harmless outside of harvest time. It may even provide benefits to growers through feeding on other pests, such as caterpillars and aphids. However, in apple and pear, the pest can be rather more damaging.

Overwintering forest bug nymphs (2nd instar) feed early in the season on developing buds, flowers and fruits (shortly after flowering). The nymphs are particularly difficult to detect as their bodies appear similar to the tree bark and are well camouflaged (Figure 1). They can also squeeze their 3 mm, small flattened bodies into the cracks and crevices of tree bark to find some shelter from the cold. Their feeding only becomes apparent long afterwards when developing apples and pears become distorted and pitted (Figure 2), and the flesh becomes discoloured. Brown lesions develop in the fruit flesh at the site of the forest bug stylet insertion, and the lesions harden, giving the fruit a 'stony' texture at harvest.

Fruit losses of 10% at harvest are common but occasionally, much higher levels of 40-50% damage have been reported, so management and control measures are becoming increasingly necessary. There is only one generation of forest bug per year and only spring control measures are generally used before or after flowering, to target the overwintering nymphs before they start to feed. With fewer effective control products available than ever before, a novel management strategy needs to be found.

Scott Raffle – see page 34.

Dr Francis Wamonje is an entomology research leader at East Malling, whose research interests include disrupting insect-mediated damage and transmission of plant pathogens and detecting pathogens in insect and plant hosts.

NIAB secured a Defra Farming Innovation Programme grant in 2022 to begin a two-year project to study the biology and control of forest bug. Collaborating with the University

Figure 1. 2nd instar nymphs are camouflaged on tree bark

Jonathan Michaelson

Figure 2. Forest bug damage to Gala apples

of Greenwich and industry partners Agrovista, Avalon Fresh and Russell IPM, orchards have been sampled for the pest and methods to rear it in the laboratory have been developed (Figure 3), whilst entrainment methods have been used to collect components of its sex pheromone.

The University of Greenwich is analysing their composition with the intention of synthesising them for use as a chemical lure in monitoring traps. Once synthesised, prototype dispensers for these lures will be manufactured and developed within a monitoring trap. Additional work is in progress to develop the optimum design of trap which could be deployed once the lure is fully developed. The use of chemical repellents in the field is also being investigated. If successful, this might lead to the testing of a 'push-pull' approach to control which NIAB has previously achieved with capsid pests in strawberry.

Figure 3. Methods to rear forest bug in the laboratory have been developed

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Identifying strawberries and raspberries with resistance to SWD

NIAB's Adam Whitehouse and Scott Raffle outline some promising results emerging from a Growing Kent & Medway funded research project.

Scott Raffle – see page 34.

Adam Whitehouse is a senior fruit breeder at NIAB East Malling, primarily focussed on strawberry genetic improvement and varietal development. In addition to commercial variety development, Adam's research interests and activities include pest and disease resistance investigations through numerous associated projects, somaclonal variation in strawberry for improved traits, developing breeding strategies for genotypes to be used in the different production and programmed systems, variety trialling and industry outreach.

Since the arrival of spotted wing drosophila (SWD) in the UK in 2012 (Figure 1), NIAB's entomologists at East Malling have led a host of industry research projects to learn more about its biology and behaviour in UK conditions and how best to manage and control it. Most recently exciting progress has been made through the use of precision monitoring in the winter months, use of bait sprays, and the development of Sterile Insect Technique (SIT) in collaboration with the commercial company BigSis.

However, one approach to control that has not been fully explored is variety resistance to the pest. Ripening soft and stone fruits are highly attractive to adult SWD (Figure 2), with the female making an incision in the skin of the fruit and laying eggs under the surface. The resulting larvae feed on the flesh of the fruit, leading to fruit collapse and an unmarketable product. If any accessions (varieties, selections or species) of soft fruits are found to have berries that are less attractive to SWD or that inhibit egg laying or larval emergence, we could then investigate the fruit traits that are associated with this and utilise such traits in soft fruit breeding programmes.

Figure 1. Adult Male SWD

In this Growing Kent & Medway funded project, NIAB is collaborating with Asplins PO and WB Chambers to screen many accessions (varieties, selections or species) of strawberry and raspberry, initially to identify if any show resistance to SWD and then find out what such resistance might be caused by.

In 2022, the focus was on strawberry and a wide range of strawberry genotypes were chosen based on their origin and pedigree. The material tested was diverse, ranging from old English bred June-bearer variety 'Cambridge Favourite', to the large, firm Californian variety day-neutral type 'Diamante'. The range included differing traits like skin colour (Figure 3), skin firmness, flesh firmness, size and sugar levels (Brix).

The aim was to identify any correlations between fruit traits and emergence of adult SWD from the fruit.

A total of 76 accessions were planted in replicated plots hosted by WB Chambers. Fruit was picked throughout the season, brought back to NIAB where fruit traits were assessed and the fruit exposed in containers to adult female SWD. The number of eggs laid in each variety was recorded and the adult females then removed. After 14 days, the number of emerging adults was counted from each of the original berries.

The results so far on strawberry have been very promising, as there was found to be statistically significant variation in the numbers of adults emerging from berries between the 76 accessions included. The genotypes used were grouped together based on the level of emergence. For those genotypes where a lack of emergence was found, several fruit quality traits were found to be correlated. In particular, the levels of Brix and the skin colour appeared to influence the level of emergence.

In 2023, the results from 2022 are being validated by re-screening those genotypes which showed either high levels of emergence or low levels of emergence. A similar exercise will also be undertaken for raspberries, looking at a wide range of accessions, including red, purple and black coloured raspberry.

Figure 2. Ripe raspberry is very attractive to SWD

Figure 3. A wide range of strawberry material has been tested for resistance to SWD

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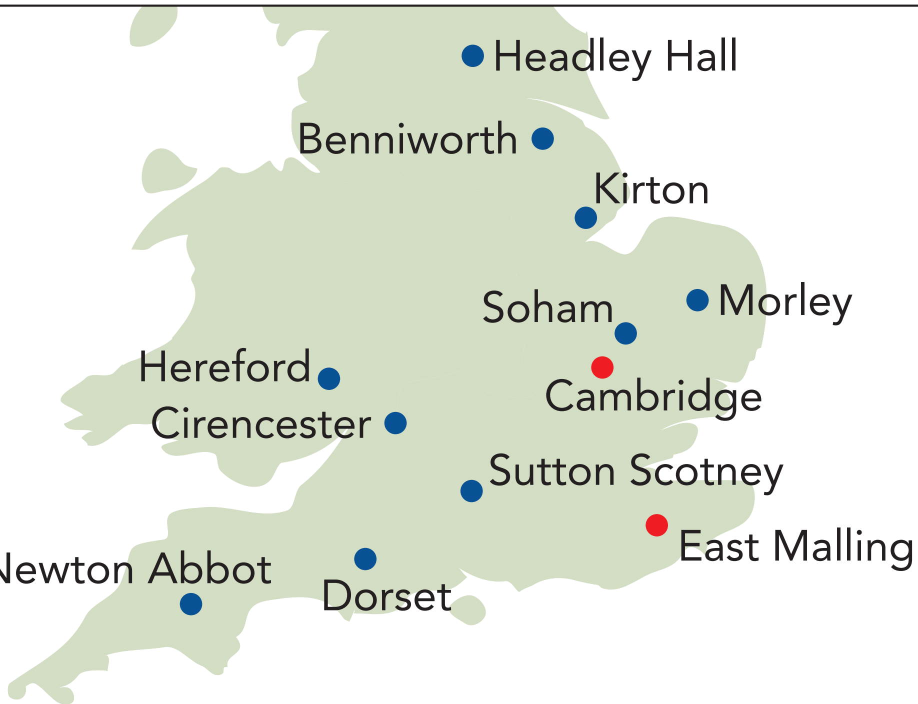

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